FDM 11-25-1 General

March 4, 2013

1.1 Design Consideration

Design an intersection to either rural or urban design criteria depending on its location and the type of existing or planned development in the area. Design intersections located to serve a present or future residential or commercial area to urban standards with specific consideration of the current or eventual need for traffic signals, roundabouts, cross walks, pedestrian signals, expected traffic volumes and size of vehicles expected. Consult with the region planning staff to determine the type of development planned in the area of the intersection.

It is very important to include Traffic Operations personnel early in the scoping of a project. Volumes, storage, geometric, and R/W needs should be addressed. It can then be determined if further involvement of Traffic Operations is needed.

Try to keep the size of intersections to a minimum. Designing intersections for large trucks requires large corner radii, which substantially increases the size of the intersection. Larger intersections generally have greater crash potential, are more difficult to delineate, may be more confusing for drivers and other users, require more right-of-way, and significantly increase pedestrian and bicycle crossing times and distances.

References for this chapter include Chapter 9 of the AASHTO GDHS[1] and other sources as noted.

Specific factors and features to consider are:

- Safety - some factors that affect intersection safety include:
  - Number of approaches
  - Number of potential conflict points
  - Type of traffic control and advance signing (see FDM 11-25-3; also, see the TGM and the TSDM and consult with Traffic Operations)
  - Approach sight distance, i.e., the visibility of the intersection to an approaching driver (see FDM 11-10-5)
  - Intersection Sight distance (see FDM 11-10-5)
  - Intersection skew angle (see FDM 11-25-2.8)
  - Whether the intersection is located on a curve (see FDM 11-25-2.9)
  - Street lighting
  - Turn Lanes (see FDM 11-25-2.2 and 2.3; also see FDM 11-25-5 and FDM 11-25-10)
  - Auxiliary lanes (see FDM 11-25-35)
  - Access management (see FDM 11-25-2.5. FDM 11-25-20, FDM 11-5-5, FDM chapter 7 and HMM Chapter 91)
  - Intersection radii and channelization (see FDM 11-25-10 and FDM 11-25-25; also see SDD 9A1)
- Functional classes of the intersecting roadways (see FDM 11-25-2, Table 2.1; also see FDM 11-15-1 Attachment);
- Designated Long Truck Routes, 75' Restricted Truck Routes, 65' Restricted Truck routes and statewide Oversized-overweight (OSOW) Freight Network (FN) (see FDM 11-25-1.4).
- Topography and surrounding land uses - examples:
  - The length of the crossroad available for traffic generating development including potential extensions
  - In urban and suburban or transitional areas, there is the potential for development to occur along the highway or adjacent frontage roads. Traffic from this development will feed into the crossroad.
  - Commercial or industrial zoned areas may attract truck terminals or other truck generators.
  - Schools, parks, residential developments are examples of destinations that should anticipate

[1] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

bicycle, pedestrian and transit increases as well as motor vehicles..

- Corridor Considerations
  - The design of an individual intersection will not only need to provide a safe environment with adequate capacity, but will also need to reflect the needs of adjacent intersections and the corridor as a whole. As such, isolated intersection designs may need to include features not dictated by capacity alone. These features should be coherent with the overall facility, examples of which may include: turn lanes, separation of turn lanes from adjacent through lanes, raised medians, islands, and separated bicycle facilities. Right-of-way may also need to be preserved for future corridor-based improvements.
- Traffic characteristics:
  - Current and expected daily traffic volumes and turning movements (see FDM 3-10-10)
  - Current and expected Design hour volumes and turning movements (see FDM 3-10-10)
  - Composition of traffic - including trucks and buses (and bicycles) (see FDM 3-10-10)
  - OSOW vehicles - including on roads that are not currently on the OSOW Freight Network, but which contain an OSOW origination point, or a recurring OSOW destination (e.g., a manufacturing plant or a gravel pit) (see FDM 11-25-1.4 and FDM 11-25-2.1.1).
  - Design vehicle (see FDM 11-25-2.1)
  - Vehicle speeds
  - Level of Service (see FDM 11-25-3 and FDM 11-5-3)
- Traffic Control Warrants and Design:
  - See FDM 11-25-3 for guidance on determining the appropriate type of intersection control
  - In general, terms, any intersection, urban or rural, that meets the criteria for a four-way stop condition or a traffic signal, also qualifies for evaluation as a modern roundabout. For more information on roundabouts, see FDM 11-26.
  - Consult with the region traffic section on the design and location of traffic signals. Applicable references include:
    - FHWA Manual of Uniform Traffic Control Devices (MUTCD) at http://mutcd.fhwa.dot.gov/,
    - Wisconsin Supplement to the MUTCD (WMUTCD) on DOTNET http://www.dot.wisconsin.gov/business/engrserv/wmutcd.htm and consultant extranet https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/index.shtm,
    - WisDOT's Traffic Signal Design Manual (TSDM) on DOTNET at http://dotnet/dtid_bho/extranet/manuals/tsdm/index.shtm and consultant extranet https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/index.shtm),
    - WisDOT's Traffic Guidelines Manual (TGM) (on DOTNET at http://dotnet/dtid_bho/extranet/manuals/tgm/index.shtm and consultant extranet https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/index.shtm)
  - Traffic signals or a roundabout may not be immediately warranted on a project but may be warranted within the project's design life. See FDM 11-50-50.2 for guidance.
- Crash experience - including numbers, rates, locations, types, and severity;
- Road user types - motorists, transit, bicyclists, and pedestrians
- Sidewalk approaches and crosswalks (see FDM 11-46-5 and FDM 11-46-10)
- Pedestrian crossing distance and Pedestrian Clearance Time
- Geometry and cross-sections of the approach roadways and the intersection;
- Drainage requirements (see FDM chapter 13)
- Proximity and traffic volumes of driveways and other roads (see FDM 11-25-2.5; also see FDM 11-5-5 and FDM 11-25-20; Refer to FDM 11-30-1 regarding ramp terminal spacing)
- Right-of-way requirements (see FDM 11-25-1.1.1)
- Cost and Potential impacts

1.1.1 Right-of-Way Considerations

Public right-of-way at STH intersections needs to accommodate design geometrics (for existing & future conditions), operations-related infrastructure, and adequate sight distance. All WisDOT maintained signal & electrical equipment must either be located within the public right-of-way or within a permanent limited easement (PLE). Such signal equipment typically includes cabinet bases, signal/lighting bases, vehicle detection, associated conductor runs, and possibly temporary signal support guy-lines. Place this equipment in locations where it is less likely to be struck by an errant vehicle - because this can reduce crash frequency and severity, as well as maintenance costs. Also, consider the placement of this equipment in relation to existing or future sidewalks or shared-use paths.

Also, consider future capacity expansion. Examples include right- & left-turn lanes, widened medians, sidewalk, bike lanes, roundabouts or interchanges. Because of these issues, involve Regional Traffic Engineering and Planning (e.g. bike/pedestrian coordinator, access management coordinator) staff in identifying required right-of-way at signalized intersections early in the design process.

1.2 Urban Intersections

At-grade urban intersections consist of a variety of types that cannot be grouped by a class of highway. Factors that influence intersection design are peak-hour traffic volumes, type and size of turning vehicles, traffic control, turning roadways, auxiliary lanes, number of lanes, divided or undivided cross section, pedestrian traffic, and right of way limitations. The proximity of commercial and industrial sites may require special designs.

Intersection geometry and operations need to accommodate all roadway users - including pedestrians and bicyclists - and provide safe travel and crossing (see FDM 11-46 for guidance on bicycle and pedestrian accommodations). Minimize the size of the intersection and the pedestrian crossing distance by designing intersection radii as small as possible. If the design vehicle is larger than a Single Unit (SU truck or a bus), consider using a two-or three centered curve. Use templates or automated programs to determine the vehicle path and then develop a two-or three-centered curve that closely emulates this path. Look at a range of vehicle turning radii and select the best fit for the design vehicle while minimizing the size of the intersection. [2]

A legal crosswalk exists at intersections, including “Tee” intersections, where the side road has sidewalks on one or both sides of the street and the through street has sidewalk on the opposite side of the street from the side road, whether the crosswalk is pavement marked or not[3]. FDM 11-46-10 further describes curb ramp installation requirements and other conditions when curb ramp installation may be desirable.

When possible, prohibit parking near the intersection on routes identified on the Long Truck Operators Map and the OSOW Freight Network to avoid conflicts with turning traffic. Large vehicles require greater turning radii and wider sweeping paths to negotiate corners. Review whether parking, roadside utilities, or street furniture will impede long truck and OSOW movements. This is of particular concern at the intersection of multiple state trunk highways in established urban environments. Certain OSOW loads (such as a bridge girder) will encroach beyond the face of curb even when the transport axles stay within the street. Refer to FDM 11-20-1 for additional Parking Lane and Border guidance.

1.3 Rural Intersections

SDD 9A1 a & b illustrate six types of rural at-grade intersection: A1, A2, B1, B2, C and D. This SDD applies to two-lane undivided and multilane divided high speed rural highways. The intersection type will indicate the length of a turn lane and shall apply to both the left turning and the right turning traffic entering the same side road leg. The lengths of the turn lanes are for deceleration only. If additional storage is needed to accommodate queuing Design Hour Traffic, or there is a high volume of truck turning movements, then provide a longer turn lane based on needed storage. Attachment 1.1 lists the criteria for using each type of intersection. FDM 11-25 Attachment 5.4 shows the median opening and non-slotted turn lanes on rural expressways.

Consider other roadways users such as pedestrian, bicyclists and transit users based on existing and future land uses. Even though these users are not typically as prevalent in rural and high speed settings as they are in urban settings, this may change with changing land uses. See FDM 11-46, “Complete Streets”, for guidance on pedestrian and bicycle accommodations. See FDM 11-25-35.3 for guidance on bus stops at intersections.

1.3.1 Intersections on Rural High-Speed Multilane Divided Highways (“Rural Expressways”)[4]

A rural high-speed (≥50 mph), multilane, divided highway with partial access control is typically referred to as a

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[2] *ORDOT Highway Design Manual (2) ORDOT Highway Design Manual ch. 9.0: Intersection and Interchange Design. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf., Ch. 9, pp.14-15, “Intersection and Interchange Design”*

[3] *Per s.340.01 (10) (b), Wis. Stats.*

[4] *From Maze et al in NCHRP Report 650 (3) NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., p.4, Background; p.147, Conclusions; pp. 1-3, Summary*

"rural expressway"[5]. Rural expressways are generally a hybrid design between a freeway and a conventional two-lane rural arterial roadway. Like freeways, rural expressways are typically four-lane divided facilities (i.e., two lanes in each direction separated by a wide, depressed, turf median), which may have grade separations and interchanges. Like conventional two-lane undivided rural arterials, expressways have partial access control allowing at-grade intersections and limited driveway access with the potential for signalization. Expressways provide many of the mobility, travel efficiency, economic and safety benefits of freeways at a far lower cost. However, increased at-grade intersection crashes and increased intersection crash severity diminish the expected safety benefits of expressways.

The typical rural expressway intersection is an at-grade two-way stop controlled (TWSC) with the stop control on the minor (usually two-lane) roadway. Expressway interchanges are generally limited to locations that meet traffic volume warrants and/or that have a disproportionate rate of serious crashes, and where the additional expenditure can be justified.

TWSC rural expressway intersections often experience safety problems long before the design life of the facility and even before meeting traffic signal volume warrants. The percentage of total expressway crashes which occur at TWSC intersections increases as the mainline traffic volumes increase and that all intersection crashes increase and become more severe as minor roadway volumes increase. Right-angle collisions are the predominant crash type at conventional TWSC rural expressway intersections. The most problematic of these (with respect to severity) tend to be those occurring in the far-side intersection (i.e., after the minor road driver has traveled through the median). The underlying cause of these collisions in most cases is not failure to yield, but the inability of the driver stopped on the minor road approach to judge the arrival time of approaching expressway traffic (i.e., gap selection).

The traditional approach to addressing safety problems at expressway intersections - after addressing potential design issues such as insufficient sight distance - is to improve the traffic-control devices, implement traffic signal control (if warranted), - and eventually construct an overpass or interchange. Traffic signals in rural areas are discouraged for several reasons including violation of driver expectations and difficulty in servicing and maintaining signals in remote locations. Signals also hamper the intended mobility of expressways. In addition, traffic signals do not always improve safety - they may only change the crash type distribution. The construction of an interchange reduces the cost advantage of building an expressway as compared with building a freeway, and the mix of at-grade intersections and interchanges tends to violate driver expectations.

1.3.1.1 Rural Expressway Intersection Safety Treatments[6]

Safety treatments for rural expressway intersections fall into three broad categories:

1. Conflict-point management strategies,
2. Gap selection aids, and
3. Intersection recognition devices.

Table 1.1 provides a listing of safety treatments by category. In general, select the most appropriate safety countermeasure based on the crash types occurring at each location. The conflict-point management strategies and the gap selection aids seem to have the most potential to improve safety at rural expressway intersections because they address the apparent underlying cause of many crashes at TWSC rural expressway intersections (i.e., far-side gap selection by crossing and left-turning minor road drivers).

[5] *Some roadways in Wisconsin are "designated expressways" per Wis Stat 84.295. The term "rural expressway" is used herein to describe a rural high-speed (≥50 mph), multilane, divided highway with partial access control, regardless of whether the roadway is "designated expressway".*

[6] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., pp. 44-63)

Table 1.1 Potential rural-expressway intersection safety treatment[7]

Category	Subcategory	No.	Safety Treatment
Conflict Point Management Strategies	Removal/ Reduction Through Access Control	1.	Conversion of entire expressway corridor to freeway
		2.	Isolated conversion to grade separation or interchange
		3.	Close low-volume minor road intersections and use frontage roads [See FDM 11-25-45]
		4.	Close median crossovers (right-in, right-out access only)
		5.	Convert four-legged intersection into T-intersection or initially construct T-intersections instead of four-legged intersections (Use a one-quadrant interchange [A] if necessary)
	Replacement of High-Risk Conflict-points	1.	J-turn intersections (indirect minor road crossing and left-turns) [A][See below]
		2.	Offset T-intersections (indirect minor road crossing)
	Relocation or Control	1.	Provide left/right-turn lanes or increase their length
		2.	Provide free right-turn ramps for exiting expressway traffic
		3.	Minimize median opening length
Gap Selection Aids	Vehicle Detection (Intersection Sight Distance Enhancements)	1.	Provide clear sight triangles [See FDM 11-10-5]
		2.	Modify horizontal/vertical alignments on intersection approaches
		3.	Realign skewed intersections to reduce or eliminate skew [See above]
		4.	Move minor road stop bar as close to expressway as possible
		5.	Provide offset right-turn lanes
		6.	Provide offset left-turn lanes [See FDM 11-10-5 and FDM 11-25-5]
	Judging Arrival Time	1.	Intersection decision support system (IDS) or other dynamic device [A]
		2.	Roadside markers/poles (static markers at a fixed distance) [A]
	Merging/Crossing Aids - (Promoting Two-Stage Gap Selection)	1.	Provide right-turn acceleration lanes for merging traffic
		2.	Expressway speed enforcement near intersections
		3.	Widen median to provide for adequate vehicle storage [See below]
		4.	Add centerline, yield/stop bars, and other signage in the median [See below]
		5.	Extend left edge lines of expressway across median opening [A]
		6.	Public education campaign teaching two-stage gap selection
Intersection Recognition Devices	Intersection Treatments	1.	Provide overhead control beacon reinforcing two-way stop control
		2.	Provide intersection lighting
	All Approaches	1.	Enhanced (overhead/larger/flashing) intersection approach signage
	Expressway Approaches	1.	Provide diagrammatic freeway-style intersection guide signs
		2.	Use of a variable median width (wider in intersection vicinity) [See below]
		3.	Change median type in vicinity of intersection
	Minor Road Approaches	1.	Use STOP-AHEAD pavement marking and in-lane rumble strips
		2.	Provide a stop bar (or a wider one)
		3.	Provide divisional/splitter island at mouth of intersection
		4.	Provide signage/marking for prevention of wrong-way entry

[A] SEEG and SWB approval is required. Coordinate with SWB on design and evaluation.

[7] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Table 19 on p. 47). (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

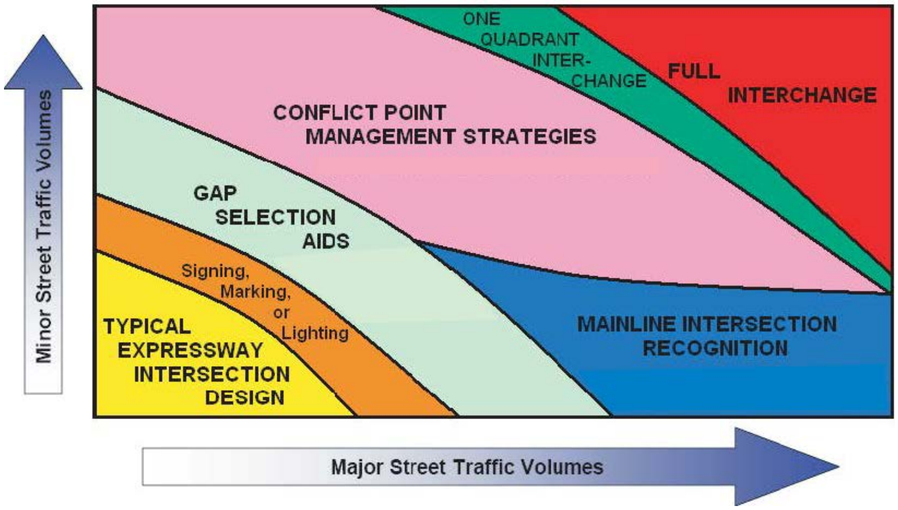

***Figure 1.1* Countermeasure matrices for TWSC expressway intersection**[8]

Conflict-point management strategies are those treatments that remove, reduce, relocate, or control the conflict-points that occur at a traditional TWSC rural expressway intersection. Conflict-points represent the locations where vehicle paths cross, merge, or diverge as they move from one intersection leg to another. A typical four-legged TWSC rural expressway intersection has 42 conflict-points, as shown in Figure 1.2 - assuming opposing left-turn paths do not overlap. Conflict-point management strategies can be expensive - and controversial because of movement restrictions and re-direction.

[8] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 117, p. 148) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

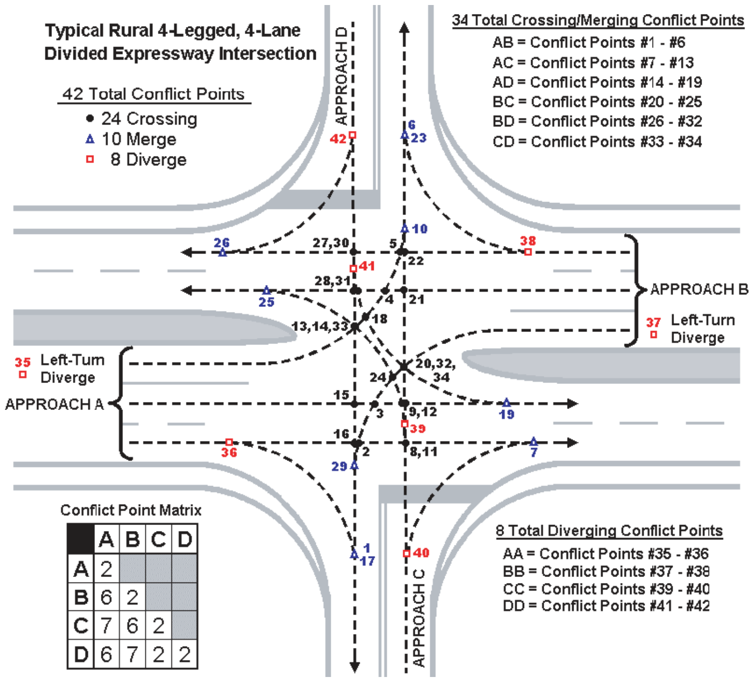

Figure 1.2 Conflict Point Diagram for expressway 4-legged intersection[9]

Intersection conflict-point analysis is a well understood means of comparing the expected safety of alternative intersection designs, which suggests that the more conflict-points an intersection design has, the more dangerous it will be. This approach is useful but limited because it assumes the crash risk is equal at each conflict point when, in fact, the crash risk associated with each conflict point varies depending on the complexity and volumes of the movements involved. The conflict-points with the greatest crash risk (i.e., those accounting for the largest proportion of crashes) at TWSC rural expressway intersections tend to be the far-side conflict-points involving minor road left-turns and crossing maneuvers (i.e., Conflict-points 15, 16, 19, 21, 22, and 25 in Figure 1.2).

The key to the effectiveness of conflict-point treatments is in eliminating the high-risk conflict-points. The conflict-point management treatments with the most potential to improve rural expressway intersection safety are those that eliminate the far-side conflict-points associated with minor road left-turns and crossing maneuvers or replace them with conflict-points of lower risk and/or severity.

[9] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 2 on p.5) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

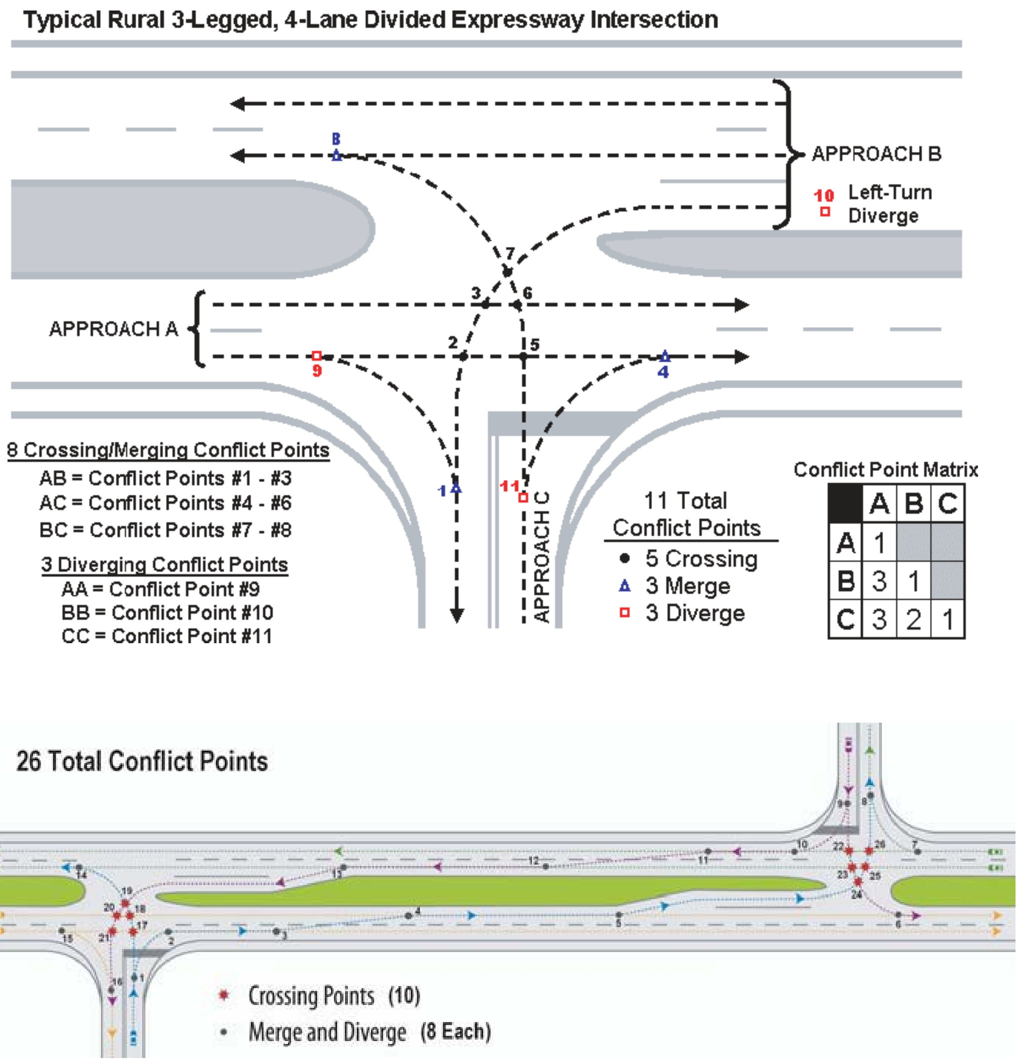

Figure 1.3 Conflict point Diagrams for expressway T-intersections[10]

Gap selection aids are those countermeasures intended to aid a driver in selecting a safe gap into or through the expressway traffic stream. Gap selection is a complex process. The driver must detect an oncoming vehicle, assess the size of the gap (i.e., time-to-arrival of the approaching vehicle) and determine whether there is enough time/space to complete their desired maneuver. The driver must then proceed and physically enter or cross through the expressway traffic stream.

Right-angle collisions are the primary safety issue at TWSC rural expressway intersections. The predominant cause of these crashes seems to be the failure of minor road drivers to detect approaching expressway traffic or their inability to adequately judge the speed and distance (i.e., arrival time) of oncoming expressway vehicles. These gap selection issues may be exacerbated by the presence of certain intersection geometric features (e.g., horizontal/vertical curvature on the mainline, intersection skew, median width, etc.); driver age, driver behavior (e.g., one-stage gap selection); and increasing traffic volumes on both of the intersecting roadways.

Intersection recognition devices are treatments that improve intersection conspicuity for drivers on either the minor road or expressway. Many TWSC rural expressway intersections are not readily visible to approaching drivers, particularly from the uncontrolled expressway approaches. As a result, crashes occur because approaching expressway drivers are unaware of the intersection and are not prepared to react to potential conflicts. Crashes also occur because drivers approaching on a sideroad do not stop at a stop sign because

[10] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 31, p.49 and Figure 65, p.86) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

they do not recognize that they are approaching a stop-controlled intersection. Providing greater intersection recognition reduces the likelihood of stop sign running, and alerts the expressway driver to proceed through the intersection with caution.

Traditionally, these treatments are the first countermeasures used when right-angle crashes begin to occur at TWSC rural expressway intersections because they are relatively low-cost and easy to deploy. However, lack of intersection recognition (i.e., STOP sign violation) is not the major contributing factor in the majority of right-angle crashes occurring at TWSC rural intersections. Therefore, these treatments do not address the predominant cause of right-angle crashes, which seems to be gap selection.

1.3.1.2 Median Width at Unsignalized Median Openings on Rural Expressways

The median width at a rural expressway intersection is usually the median width for the entire expressway corridor. However, the major function of a median differs between intersections versus at intersections. The major function of the median between intersections is to separate opposing expressway traffic; the major function of the median at intersections is to provide a refuge area for left-turning and U-turning expressway traffic as well as for left-turning and crossing traffic from the minor road. A median width of 40-feet or wider is adequate for expressway drivers to experience a sense of separation from opposing traffic. However, research has shown that wider medians are safer at unsignalized TWSC rural expressway intersections, most likely because wider medians allow for two-stage gap selection (i.e., a minor road driver can safely stop in the median area to evaluate the adequacy of the gap in expressway traffic coming from the right before completing a crossing or left-turn maneuver).[11] A wider median at an intersection also serves as an intersection recognition device for expressway traffic by emphasizing the presence of the upcoming intersection.

The minimum median width at an intersection needed for two-stage gap selection is the length of the design vehicle plus 3-feet of clearance to the expressway thru-lanes from both the front and the rear of the vehicle. However, some drivers may perceive this as being too narrow because it places them across the expressway left-turn lane(s). These drivers may feel that they have no option but to complete the crossing or left-turning maneuver in one stage. Therefore, it is desirable to provide additional median width so that vehicles stored in the median do not block the expressway left-turn lane approaching from their right but still have a minimum 3-foot clearance from the expressway thru-lanes. Additional median width may also be desirable to allow more of the deceleration to take place within the median.

The standard median width of 50 or 60-feet will provide storage for cars or small trucks, but is not adequate for storing long trucks or combinations of connected farm equipment. Provide a wide median where possible if the divided highway intersects a side road on a curve or at any location to accommodate long trucks or combinations of farm machinery. The median should be at least 100 feet wide, up to approximately 150 feet wide to accommodate long trucks like the WB-65 or combinations of farm machinery that produce a long train of connected equipment.

Median roadways wider/longer than 150 feet can cause problems as well. Consider appropriate signing to prevent Wrong Way entry onto the expressway facility.

There are fewer operational problems at rural unsignalized intersections as the median width increases, but the rate of undesirable maneuvers increases as the median opening length increases.[12] In other words, the geometrics of a wide median in combination with a smaller median opening help create the impression that there is not much choice in traversing the median except to follow the path the designer intended. Median delineation is another way to emphasize this desired path.

1.3.1.3 Median Signage and Delineation[13]

Median signage and delineation have four major objectives:

1. Inform minor road drivers that they have reached a divided highway intersection;
2. Establish the right-of-way between median and far-side expressway traffic;
3. Communicate the appropriate gap selection process (i.e., one or two-stage); and
4. Define the proper travel paths through the median roadway.

[11] See Harwood et al in NCHRP Report 375 (*4) NCHRP Report 375*: *Median Intersection Design*. TRB, National Research Council, 1995.

[12] See Harwood et al in NCHRP Report 375 (*4) NCHRP Report 375*: *Median Intersection Design*. TRB, National Research Council, 1995.

[13] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., pp. 58-59)

If a median is wide enough to store a passenger car, then stop or yield bars in conjunction with STOP or YIELD signs may be used to establish right-of-way and to communicate the appropriate two-stage gap selection behavior to the minor road driver. Generally, median yield control is encouraged unless the selected design vehicle can be completely stored within the median area. Do not use this marking and signing if the median is not wide enough to store a passenger car, i.e., if all vehicles require one-stage gap selection.

On median roadways wider than 120 feet, provide double yellow pavement marking to separate the opposing traffic and provide stop bars and STOP signs at each end of the median roadway. These signs/markings effectively provide a measure of depth perception to communicate to the minor road driver that the median is wide enough for vehicle storage, thereby promoting two-stage gap selection behavior. Often, rural expressway intersections with wide medians have large expanses of pavement that can make it difficult for drivers to decide what path to follow and to anticipate the paths other drivers will take. The double yellow median centerline should help to provide visual continuity with the centerline of the minor road approaches and to define the desired vehicle paths through the median roadway. Slotted left turn lanes are generally not desirable for this configuration.

1.3.2 J-Turn Intersection

The J-turn is an example of a reduced-conflict intersection that WisDOT has used on expressways. Justify selection of a J-turn or other reduced-conflict intersections (or interchanges) using the Intersection Control Evaluation (ICE) process described in FDM 11-25-3. J-turn implementation on WisDOT projects will be on a pilot basis for the time being. Regions must coordinate with BPD and BTO in the evaluation and design.

The J-turn intersection combines a directional median (which allows direct left-turn exits from the expressway, but prohibits sideroad traffic from entering the median) with downstream median U-turns. Left turning and crossing traffic from the sideroad makes these maneuvers indirectly by turning right, weaving to the left, making a downstream U-turn, and then returning to the intersection to complete their desired maneuver.

Since there is no indication that U-turns at unsignalized median openings constitute a safety concern[14], the J-turn intersection design effectively replaces the high risk, far-side conflict-points associated with direct minor road left-turns and crossing maneuvers (i.e., Conflict-points 15, 16, 19, 21, 22, and 25 in Figure 1.2) with less risky conflict-points associated with right-turns, U-turns, and weaving maneuvers. The J-turn intersection reduces the total number of intersection conflict-points at a typical TWSC rural expressway intersection from 42 to 24 (as shown in Figures 1.2 and Figure 1.4, respectively).

Figure 1.4 Conflict Point Diagram for J-turn Intersection[15]

TWSC rural expressway intersections most likely to benefit from J-turn intersection conversion include:

- Intersections with a history of far-side right-angle collisions, collisions within the median, and/or "left-turn leaving" collisions;

[14] See Potts et al in NCHRP Report 524 (*5) NCHRP Report 524*: *Safety of U-Turns at Unsignalized Median Openings*. Transportation Research Board of the National Academies, 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_524.pdf.

[15] From Maze et al in NCHRP Report 650 (*3) NCHRP Report 650*: *Median Intersection Design for Rural High-Speed Divided Highways*. Transportation Research Board of the National Academies, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf., Figure 48, p. 65) (NCHRP references from "NCHRP Report 650" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

- Intersections with high volumes of traffic on the mainline creating infrequent safe gaps for direct crossing or left-turn maneuvers, while still having frequent enough gaps for safe right-turn entry
- Intersections with relatively low volumes of traffic crossing or turning left from the minor roads; and
- Intersections with poor horizontal and/or vertical alignment

Limited experience with the J-turn intersection design on rural expressways in Maryland and North Carolina have shown that the design can offer superior safety performance as compared with a typical TWSC rural expressway intersection. The implementation at the four sites examined completely eliminated far-side right-angle collisions and improved overall safety.

There are some potential issues in using J-turns at high-speed rural expressway intersections because J-turns are a relatively recent application:

- Design guidance and standards are still evolving. - There are no traffic volume or level-of-service warrants.
- Signing and marking – a J-turn essentially creates three (3) separate intersections and drivers need clear and timely direction in order to make the correct decision.
- Public acceptance

J-turn design considerations include:

- Operational and safety comparison with other intersection alternatives using the ICE process described in FDM 11-25-3
  A J-turn is essentially three separate intersections. Each of these intersections are evaluated separately but compared collectively to other intersection alternatives
- Intersection Sight Distance (ISD)
  The ISD for the mainline left turn into the side road is based on Case F; the ISD for the u-turn locations is based on Case B1; the ISD for the sideroad right turns is based on Case B2 (see FDM 11-10-5.1.4)
- Separation between the sideroad intersection and the u-turn locations - this distance represents a trade-off between providing sufficient space for safe/functional weaving, U-turn storage, and approach signing, while minimizing the travel distance/time of the indirect left-turn and crossing maneuvers. Use the following guidelines:
  - As a rule of thumb, provide 7-10 seconds per lane[16] to the begin taper for the U-turn lane - and check the adequacy during design (e.g., a vehicle crossing 2-lanes at 70 mph requires 1450-feet using 7-sec per lane; and 2060-feet using 10-sec per lane);
  - Do not place median openings within the functional length of intersection of any of the three intersections comprising the j-turn;
  - Provide adequate distance for advance signing
  - Do not locate u-turns opposite driveways or streets
  - Check weaving
- Geometry
  - Provide positive offsets for opposing left turn lanes
  - Accommodate u-turning vehicles. Possible treatments include increased median width, loons, and jughandles;
  - Consider positive offsets for right turn lanes
  - Side road islands and directional median islands need to reinforce left-out and thru movement restrictions
  - Checking and accommodating OSOW vehicles if required (see Table 2.2 and Figure 2.5; coordinate with the region freight operations unit)
  - Accommodate bicyclists and pedestrians if appropriate

1.4 Truck Routes and Routes for Oversized-Overweight (OSOW) Vehicles

There are three (3) categories of truck routes on the STH:

1. “Designated Long Truck Routes” (no overall length limitation; MAX 53' trailer w/ 43' king pin to rear axle; MAX 28’-6” trailers on double bottoms).
2. “75' Restricted Truck Routes” (75-ft overall length limitation; MAX 53' trailer, 43' king pin to rear axle;

[16] *(6) Innovative Intersection Designs. (DRAFT PowerPoint presentation for 2009 ACEC/WisDOT Transportation Improvement Conference).* SRF Consulting Group, Inc., 2009.

no double bottoms).

3. “65' Restricted Truck Routes” (65-ft overall length limitation; MAX 48' trailer, no double bottoms).

See SS 348 and Administrative Code Trans 276 for requirements and definitions for these routes. Trans 276 has a listing of “Designated Long Truck Routes” and for a listing of 65’ Restricted Truck Route (Note: there are non-STH routes on this list as well). If a STH is not listed as either a “Designated Long Truck Route” or a “65' Restricted Truck Route” then it is a “75' Restricted Truck Route”. The “Wisconsin truck operator map” includes these identified routes and is available at http://www.dot.wisconsin.gov/travel/maps/truck-routes.htm.

All Federally Designated Truck Routes in Wisconsin are Wisconsin “Designated Long Truck Routes” as listed in 23 CFR 658, Appendix A, but not all Wisconsin “Designated Long Truck Routes” are Federally Designated Truck Routes. The design requirements for Federally Designated Truck Routes differ somewhat from other Wisconsin “Designated Long Truck Routes” (see FDM 11-15-1, FDM 11-20-1).

Oversized-overweight (OSOW) vehicles are those vehicles that exceed the maximum requirements for a route. These vehicles require a permit[17].The required permits fall into two general categories: (1) single-trip; and (2) multiple-trip. See FDM 11-25-2.1.1 for more information on OSOW vehicles.

WisDOT has established a statewide OSOW Freight Network (FN) for the use of permit OSOW vehicles, based on routes that these vehicles have used in the past, and on projected requirements. The statewide OSOW FN is a subset of “Designated Long Truck Routes”, i.e., all roads on the FN are on “Designated Long Truck Routes”, with the exception of a few roadways that may be an origination point or a recurring destination point, such as a manufacturing plant or a gravel pit.

The OSOW Freight Network map is available at the following link, http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf. See FDM 11-25-2.1.1 for a discussion and description of OSOW vehicles.

See the following sections of FDM 11-25 for additional design guidance for intersections on the OSOW FN:

FDM 11-25-1 General
- 1.1 Design Considerations
- 1.2 Urban Intersections
- 1.3 Rural Intersections
  - 1.3.2 Jturn intersection
- 1.4 Truck Routes and Routes for OversizedOverweight (OSOW) Vehicles

FDM 11-25-2 Design Criteria and Guidelines
- 2.1 Design Vehicles
  - 2.1.1 OSOW vehicles
    - 2.1.1.1 SingleTrip Permit OSOW vehicles (OSOWST)
    - 2.1.1.2 MultipleTrip Permit OSOW vehicles (OSOWMT)
    - 2.1.1.3 OSOW Vehicle Inventory Evaluation Overview
  - 2.1.2 Selecting Vehicles for Intersection Design
    - Table 2.2 intersections Where Checking OSOWST or OSOWMT Vehicles is Required
    - Figure 2.5 WisDOT’s Interim Policy on Checking Criteria for OSOWST and OSOWMT Vehicles at intersections
- 2.2 Physical and Functional Areas of an Intersection
- 2.2.2 Upstream Functional Length of Intersection
    - Table 2.5 Queue Storage (d4) for STH Intersections [A] [B] [C]
- 2.3 Turn Bays
    - Table 2.6 FullWidth TurnLane Length for Urban Streets and Low Speed Rural [A]
- 2.5 Intersection Vertical Alignment
- 2.7 Angle of Intersection

FDM 11-25 Attachment 2.1 WisDOT Vehicle Inventory of OSOW Vehicles

[17] SS 348.25(1) states “No person shall operate a vehicle on or transport an article over a highway without first obtaining a permit therefore as provided in s. 348.26 or 348.27 if such vehicle or article exceeds the maximum limitations on size, weight or projection of load imposed by this chapter.”

FDM 11-25-3 Intersection Control Evaluation

3.2.2 Alternative Selection

Table 3.1 Intersection Control Evaluation Alternative Selection

3.2.3 Appendices to Attach

FDM 11-25-5 LeftTurn Lanes

5.2 Warranting Criteria

5.3 Design Criteria

5.3.2 Median End Treatment

5.4 Special Designs

5.4.1 Slotted LeftTurn Lanes

FDM 11-25-10 RightTurn Lanes

10.2 Intersections in Rural and Developing Areas

10.2.1 Storage Length

FDM 11-25-15 Turning Roadways (Channelized Right)

15.1 Criteria

FDM 11-25-25 Channelization

25.2 Islands

FDM 11-25-40 Railroad Crossings

40.1 General

1.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

2. ORDOT Highway Design Manual ch. 9.0: Intersection and Interchange Design. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf. Accessed 8-6-2010.

3. Maze, T. H., J. L. Hochstein, R. R. Souleyrette, CTRE - Iowa State University, H. Preston, and R. Storm. NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways. Transportation Research Board of the National Academies, Washington, DC, 2010. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_650.pdf. Accessed 5-18-2010. [18]

4. Harwood, D. W., M. T. Pietrucha, M. D. Wooldridge, R. E. Brydia, and K. Fitzpatrick. NCHRP Report 375: Median Intersection Design. TRB, National Research Council, Washington, DC, 1995.

5. Potts, I. B., D. W. Harwood, D. J. Torbic, K. R. Richard, J. S. Gluck, H. S. Levinson, P. M. Garvey, and R. S. Ghebrial. NCHRP Report 524: Safety of U-Turns at Unsignalized Median Openings. Transportation Research Board of the National Academies, Washington, DC, 2004. http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_524.pdf.

[18] [Dec 3, 2012 email from Ellen Chafee, Editor, CRP-TRB] The TRB through the National Academy of Sciences (NAS) grants permission to use the material listed below from Maze et al. (2010) NCHRP Report 650:Median Intersection Design for Rural High-Speed Divided Highways and J. A. Bonneson and M. D. Fontaine (2001) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements in a proposed revision to Chapter 11, Section 25 of Wisconsin DOT's Facilities Development Manual (FDM 11-25).

NCHRP Report 650 Table 19 p. 47
NCHRP Report 650 Figure 117p. 148
NCHRP Report 650 Figure 31 p. 49
NCHRP Report 650 Figure 65 p. 86
NCHRP Report 650 Figure 48 p. 65
NCHRP Report 457 Figure 2.6 p. 23
NCHRP Report 457 Figure 2-6.xls Interactive spreadsheet in online version

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Permission is also provided on condition that appropriate acknowledgment will be given as to the source material.

6. Eyler, D. Innovative Intersection Designs. (DRAFT PowerPoint presentation for 2009 ACEC/WisDOT Transportation Improvement Conference). SRF Consulting Group, Inc., Plymouth, MN, Feb. 25, 2009.

LIST OF ATTACHMENTS

Attachment 1.1 Selection Criteria for Rural High Speed Intersections

FDM 11-25-2 Design Criteria and Guidelines March 4, 2013

2.1 Design Vehicles

AASHTO[19] has established four (4) general classes of standard vehicles:

1. *Passenger cars* - includes passenger cars of all sizes, sport/utility vehicles, minivans, vans, and pick-up trucks.
2. *Buses* - include inter-city (motor coaches), city transit, school, and articulated buses
3. *Trucks* - includes single-unit trucks, truck tractor-semitrailer combinations, and truck tractors with semitrailers in combination with full trailers
4. *Recreational vehicles* - includes motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, and motor homes pulling cars.

For purposes of geometric design, each standard vehicle has larger physical dimensions and a larger minimum turning radius than those of almost all vehicles in its class. [20]

For intersection geometric design, the most important attribute of a vehicle is its turning radius, which affects the pavement corner radius, left-turn radii, lane widths, median openings, turning roadways, and ultimately, the size of the intersection. A vehicle may also affect the choice of traffic control device and the need for auxiliary lanes.[21]

The turning radius of a vehicle determines the ease and comfort of making the turning maneuver. The smaller the turning radius, the larger the off-tracking of the vehicle and the slower the speed. Forcing large vehicles to use very small turning radii forces the driver to perform a very slow maneuver. Tighter radii are typically chosen for low speed and/or urban intersections, while larger radii are selected for higher speeds and rural intersections. [22,23]

See the following sections in chapter 9 of the 2004 AASHTO GDHS[24] for guidance on turning paths, clearances, encroachments and assumed speed of turning vehicles at intersections:

Right-turning vehicles:

- Types of Turning Roadways; pp.583-621
- Turning Roadways with Corner Islands; pp.634-639
- Free-Flow Turning Roadways at Intersections; pp.639-639

Left-turning vehicles:

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[19] AASHTO GDHS 2004 (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., Ch. 2, p.15, “Design Vehicles / General Characteristics”

[20] Florida Intersection Design Guide 2007 (*7) Florida Intersection Design Guide*. Florida DOT, 2007. http://www.dot.state.fl.us/rddesign/FIDG-Manual/FIDG2007.pdf. sect. 3.4, “Design Vehicles”

[21] MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project Development & Design Guide ch. 6*: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf., Sect. 6.3.3, “Motor Vehicles

[22] ORDOT Highway Design Manual (*2) ORDOT Highway Design Manual ch. 9.0*: *Intersection and Interchange Design*. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf., Ch. 9, pp.14-15, “Intersection and Interchange Design”

[23] ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-1.08(a), “Design Vehicles Types”

[24] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

- Median Openings; pp.689-704
- Auxiliary Lanes; pp.713-723

2.1.1 OSOW Vehicles

See FDM 11-25-1.4 for a discussion of the OSOW Freight Network (FN). OSOW vehicles are non-standard vehicles that exceed the maximum requirements for a route and that require a permit[25]. OSOW vehicles fall into two general categories:

1. Single-trip permit OSOW vehicle (OSOW-ST) (see FDM 11-25-2.1.1.1)
2. Multiple-trip permit OSOW vehicle (OSOW-MT) (see FDM 11-25-2.1.1.2) (Note: Although a combine is listed as an OSOW-MT, it is an implement of husbandry and does not require a permit.)

The OSOW vehicle inventory on Attachment 2.1 shows vehicles of various configurations for which templates are available for use with truck turning software to check if the OSOW vehicles will be able to negotiate an intersection.

Figure 2.5 shows WisDOT's interim policy for checking OSOW-ST and OSOW-MT vehicles at intersections. Table 2.2 shows intersections where checking OSOW-ST and OSOW-MT vehicles is required. See FDM 11-25-2.1.1.1 and FDM 11-25-2.1.1.2 for guidance on accommodating OSOW vehicles.

2.1.1.1 Single-Trip Permit OSOW Vehicles (OSOW-ST)

Single-trip permit OSOW vehicles (OSOW-ST) are very large loads that exceed legal length, height, weight and/or width. The permits are on a load specific and route-specific basis. These vehicles generally have an overall length greater than 110 feet, and typically are required to incorporate rear steering maneuverability. Escorts are typically required.

There are five (5) representative Single-trip permit OSOW vehicles (OSOW-ST) shown on the WisDOT vehicle inventory (see Attachment 2.1, pages 1-2):

1. 5-axle expandable-deck lowboy (DST Lowboy)
2. Wind Tower Upper-Mid Section, 79.5' L x 11.5' W
3. Wind Tower Section, 78' L x 14.7' W
4. 55 Meter Wind Blade
5. 165' Beam

It is estimated that if these five (5) vehicles are accommodated by the intersection then other OSOW-ST vehicles will be accommodated as well.

On new construction, reconstruction and pavement replacement projects, identify and check the specific through and turning movements of OSOW-ST vehicles at each intersection on the OSOW Freight Network(FN) (or on non-FN routes where OSOW-ST vehicles are known to travel), including intersections with other FN routes (see Table 2.2). Examples include:

- Turning movements onto county or local roads to the OSOW-ST origin such as a manufacturing plant or gravel pit
- Freeway interchange off-on ramp terminals at the crossroad for a through movement,
- A turning movement where it is known that the OSOW-ST loads will turn.
- Through or turning movements at a roundabout (see FDM 11-26)
- Through movement from a stop-controlled side road across a non-stop controlled mainline

There may be special design considerations to accommodate OSOW-ST vehicles. The frequency of these OSOW-ST loads is critical when considering the type of special design that may be used. Some examples of special designs to accommodate OSOW-ST vehicles include:

- Curbs that are traversable (e.g., sloping face curbs that are 4-inches or lower) by OSOW-ST vehicles, or
- Allow counter directional travel on a right-turn bypass lane, or
- Provide a gated bypass lane just for the OSOW-ST vehicles to use.

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[25] SS 348.25(1) states "No person shall operate a vehicle on or transport an article over a highway without first obtaining a permit therefore as provided in s. 348.26 or 348.27 if such vehicle or article exceeds the maximum limitations on size, weight or projection of load imposed by this chapter."

- Full depth shoulders
- Wide shoulders
- Stabilized/paved areas behind curbing
- Relocation of signals, poles, signs, street appurtenances, etc
- Removable signs and street appurtenances[26]
- On new construction, reconstruction and pavement replacement projects being designed with Civil 3D software and using a 3D model, design pavement grades and cross slopes to ensure sufficient vehicle body clearance so that vehicles can make the required movements without "hanging up". This is particularly important for the 5-axle expandable-deck lowboy (DST Lowboy).

Coordinate the OSOW Freight Network intersection maneuverability check with the Regional freight operations unit.

2.1.1.2 Multiple-Trip Permit OSOW Vehicles (OSOW-MT)

Multiple-trip permit OSOW vehicles (OSOW-MT) exceed the legal semi truck criteria to use the highway system. The permits are not load specific or route specific. Multiple Trip permits authorized by 348.27(2) and (7) may travel on any road or over any bridge (including culverts), unless the roadway or structure has been restricted in a manner consistent with various laws authorizing local or State personnel to restrict, e.g., weight posting. The envelope for these multiple trip permits are: 16' high; 15' wide; 100' long and 170k gvw[27]. Since OSOW-MT vehicles have an overall length of less than 110 feet they are not required to incorporate rear steering maneuverability. Escorts are typically not required.

There are about 15,000 to 17,000 multi-trip permits issued on an annual basis, which account for 300,000 to 400,000 loads per year. There are three (3) representative OSOW-MT vehicles shown on the WisDOT OSOW vehicle inventory (see Attachment 2.1, page 1)

1. 80' Mobile Home
2. WisDOT WB-92 (formerly WisDOT WB-67-Long)
3. Combine*

* A combine is a representative vehicle for implements-of-husbandry (IOH). Although shown as a Multiple-trip permit OSOW vehicle (OSOW-MT), implements-of-husbandry do not require permits. The primary reason the combine is in the OSOW inventory is because it has a 20' width and can be problematic at single lane roundabouts (or any narrow roadway) for signs, power poles, light poles to make sure they are far enough from the roadway.

On new construction, reconstruction and pavement replacement projects identify and check the specific through and turning movements of OSOW-MT vehicles at STH intersections with an STH or a truck route or at truck route intersections with an STH or a truck route (unless restricted as noted above). Also, check OSOW-MT movements at the same intersections as OSOW-ST movements (see FDM 11-25-2.1.1.1 and Table 2.2).

The WB-92 (formerly WB-67-Long) is a very challenging vehicle to accommodate at an intersection because of its length and its lack of rear steering. Check if each required check movement of the WB-92 vehicle will fit through an intersection or make turns at an intersection without tires going over the curbs or having to remove signals, light poles or signposts. Lane encroachments and full use of roundabout truck aprons are acceptable. Describe and document in the DSR the required WB-92 check movements that cannot be accommodated at an intersection without excessive impacts. Also, discuss possible alternative routes for those movements

Coordinate the intersection maneuverability check with the Regional freight operations unit.

2.1.1.3 OSOW Vehicle Inventory Evaluation Overview

Use AutoTURN or AutoTrack software for OSOW horizontal evaluation (see FDM 11-26-50, Attachment 50.3) and AutoTrack Pro for low clearance evaluation (DST lowboy). Refer to these links for videos and assistance in using these tools.

This is the link to the AutoTURN Pro tutorial videos:

ftp://ftp.dot.wi.gov/dtsd/bpd/methods/ground-clearance-training

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[26] NYSDOT Highway Design Manual (*10) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2006. https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_05.pdf., Sect. 5.7.1.3, "Oversized Vehicles"

[27] gvw = gross vehicle weight

The following OSOW-ST vehicles in the OSOW library have rear steering capabilities:

- 55 Meter Wind Blade
- 165' Beam
- Wind Tower Section, 78’L x 14.7’W

The easiest of these three is the Wind Tower Section 78’L x 14.7’W because the rear steering is linked to the front. Just drive the vehicle and the rear steers itself.

The 55 Meter Wind blade and the 165' Beam are a little more complicated because they have rear steering that is completely independent of what the front axle is doing. For those, when you initiate a swept path command, you will see a check box called "Override Angle". You need to check that box to control the steering of the rear axles (see Figure 2.1). In AutoCAD Civil 3D, the rear steering is then controlled by holding the Ctrl key and using the wheel on your mouse as you move through the swept path.

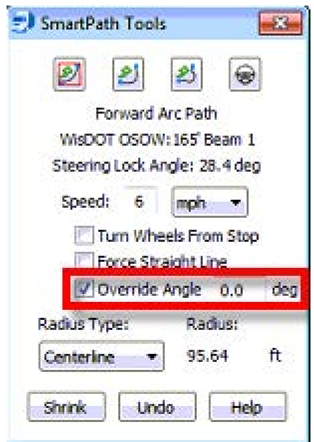

Figure 2.1 Checkbox to Control Rear Steering

2.1.2 Selecting Vehicles for Intersection Design[28] and OSOW Vehicle Checks

Turning movements control the operations, safety, and efficiency of an intersection. If intersection geometry restricts vehicles from properly completing turning maneuvers then capacity is reduced, crash potential increases and the intersection will potentially break down. Each leg of an intersection handles the turning movements of various vehicle types with varying degrees of encroachment.

Intersection Design Vehicle (IDV). An Intersection Design Vehicle for an intersection turning movement is the largest standard vehicle that frequently makes that turning movement. An Intersection *Design Vehicle* makes the turning movement *without* encroaching onto other lanes (including a contiguous bike lane between a right turn lane and a travel lane - as illustrated in Figure 2.2 on the EB approach leg) and *without* encroaching onto the shoulder or gutter. Such designs help reduce collisions and operational delays from lane encroachments. (Note: A *right-turning* Intersection *Design Vehicle* may encroach onto a bike lane that is contiguous to the gutter, i.e., to the right of a right-turning vehicle- as illustrated in Figure 2.2 on the EB departure leg).

Intersection Check Vehicle (ICV). An Intersection Check Vehicle for an intersection turning movement is larger than the Design Vehicle and makes the turn less frequently than the Design Vehicle. An Intersection *Check*

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[28] ORDOT Highway Design Manual (*2) ORDOT Highway Design Manual ch. 9.0*: *Intersection and Interchange Design*. Oregon Department of Transportation, 2008. ftp://ftp.odot.state.or.us/techserv/roadway/web_drawings/HDM/Rev_E_2003Chp09.pdf., Ch. 9, pp.14-15, “Intersection and Interchange Design”
NYSDOT Highway Design Manual (*10) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2006. https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_05.pdf., Sect. 5.7.1, “Design Vehicle”
ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-2.01(c), “Encroachment”
MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project Development & Design Guide ch. 6*: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf., Sect. 6.7.2, “Pavement Corner Radius”; Sect. 6.7.2.1, “Simple Curb Radius”

Vehicle makes the turning movement by swinging wide and encroaching onto other traffic lanes (including bike lanes) without disrupting traffic significantly. Desirably an Intersection Check Vehicle will not encroach into opposing travel lanes or leave the roadway (i.e., drive up on the curb or encroach beyond the shoulder), but this is not always practical or cost effective - particularly for OSOW vehicles or for turns made from/to low-speed, low-volume local streets in urban areas.

For design purposes, assume that parking stalls are occupied and therefore unavailable for the movements of Intersection Design Vehicles and Intersection Check Vehicles.

Figure 2.2 illustrates the concept of Intersection Design Vehicle vs. Intersection Check Vehicle.

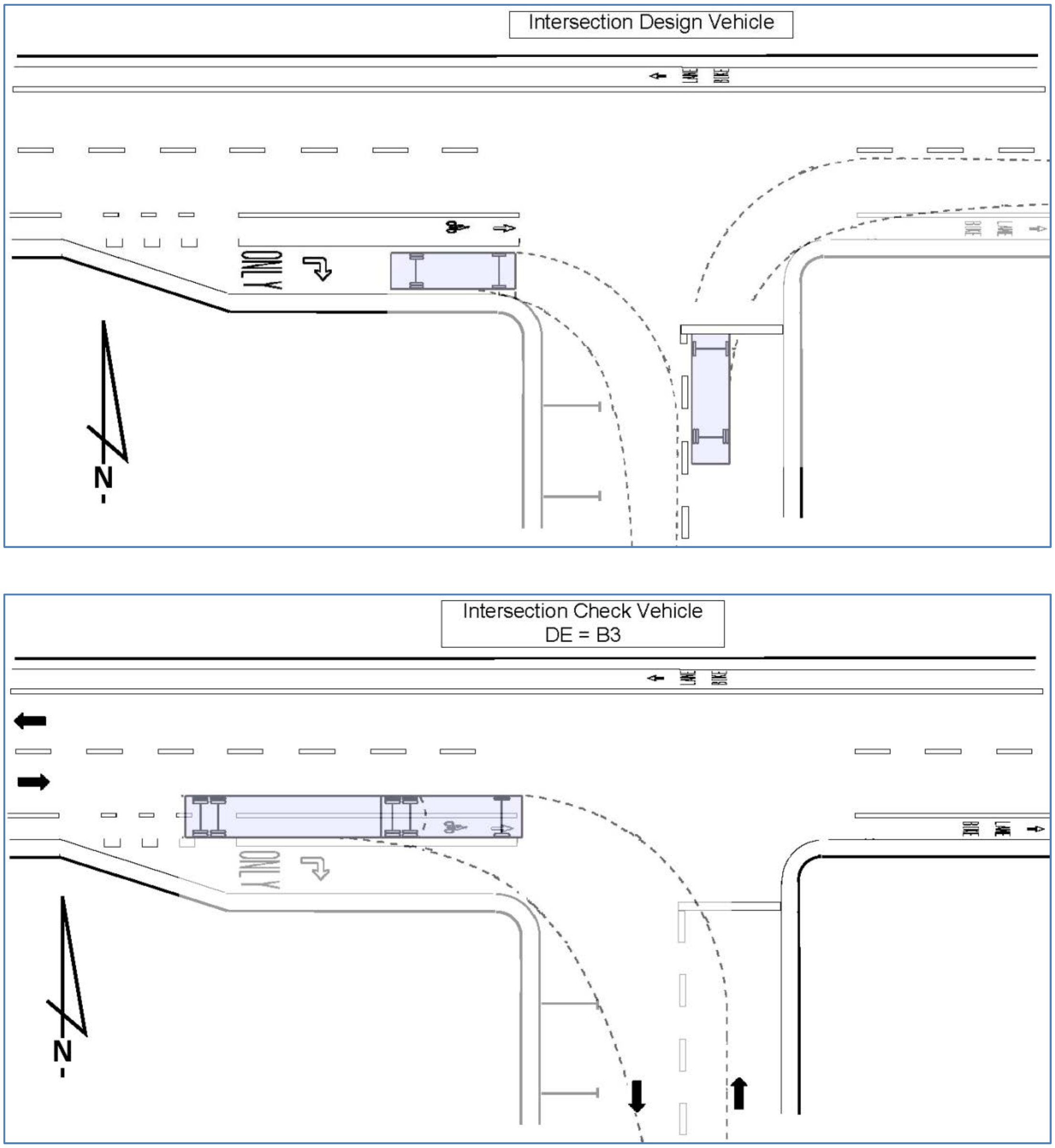

Figure 2.2 Illustrative Turning Movements for Intersection Design and Check Vehicles

Figure 2.3 illustrates and defines the possible degrees of encroachment for intersection turning movements. The acceptable degree of encroachment for a particular vehicle type varies significantly depending on roadway type and balances the operational impacts to turning vehicles with the safety of all other users of the street.

Figure 2.4 illustrates "effective" pavement width on approach and departure legs. The "effective" pavement width is the pavement width usable under the permitted degree of encroachment. At a minimum, effective pavement width is always the right-hand lane and therefore usually at least 11-12 feet, on both the approach and departure legs. Typically, legs with on-street parking have an effective pavement width that ranges from about 20-feet, if there is no bike accommodation, to about 25-feet if there is a bike accommodation. The effective width may include encroachment into adjacent or opposite lanes of traffic, where allowed.

Table 2.1 shows the default Design Vehicle for intersection turning movements, based on the functional classifications of the intersecting highways. Potentially, each turning movement at an intersection could have a different Design Vehicle.

Table 2.1 also shows Check Vehicles and their acceptable degrees of encroachment (see Figure 2.3), based on the functional classifications of the intersecting highways.

Use Table 2.1 in conjunction with Figure 2.3 and 2.4 as a starting point for planning and design. Verify the acceptable degree of encroachment during the project development process. Considerations include traffic volumes, one-way or two-way operations, urban/rural location, construction impacts, right-of-way impacts and the type of traffic control.

Figure 2.5 shows WisDOT's interim policy on checking criteria for OSOW-ST and OSOW-MT vehicles at intersections. Table 2.2 shows intersections where checking OSOW-ST and OSOW-MT vehicles is required. See FDM 11-25-2.1.1.1 and 2.1.1.2 for guidance on accommodating OSOW vehicles.

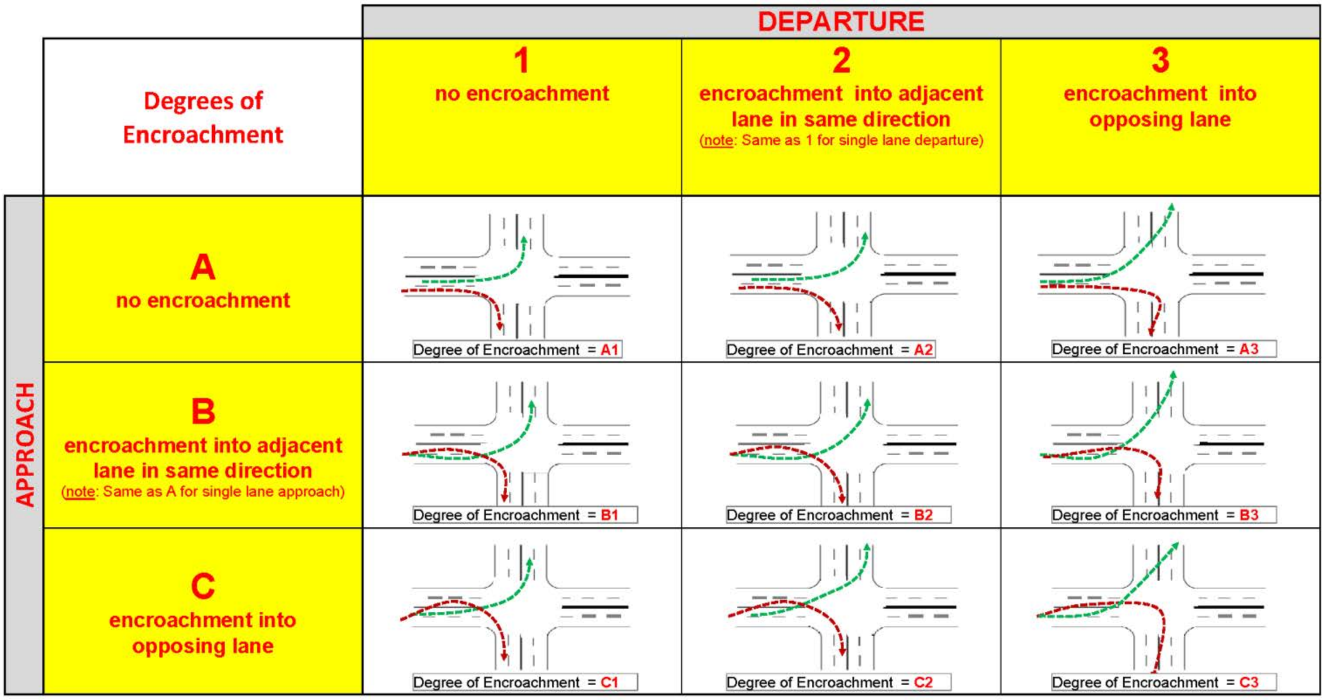

***Figure 2.3* Degrees of Encroachment**[29]

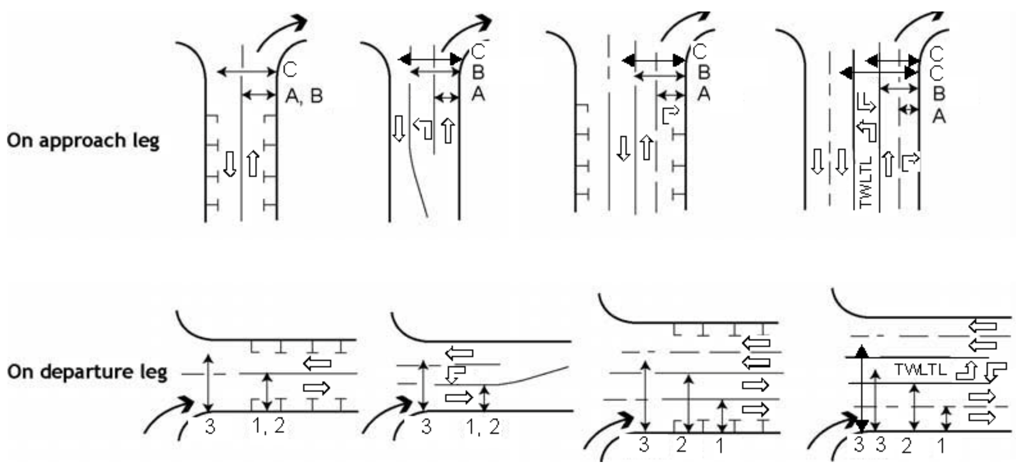

***Figure 2.4* Effective Pavement width and effect on degree of encroachment**[30]

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[29] Adapted from MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project Development & Design Guide ch. 6*: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf., Sect. 6.7.2, "Pavement Corner Radius", Exh. 6-15, "Typical Encroachment by Design Vehicle"

[30] MADOT Highway Department Project Development & Design Guide (*8) MADOT Highway Department Project Development & Design Guide ch. 6*: *Intersection Design*. Massachusetts Department of Transportation - Highway Division, 2006. http://www.mhd.state.ma.us/downloads/designGuide/CH_6_a.pdf., Sect. 6.7.2, "Pavement Corner Radius", Exh. 6-17, "Effective Pavement Widths"

***Table 2.1* Default Intersection Design and Check Vehicles & Degree of Encroachment [DE] [A]**

For Turn Made		Intersection Design Vehicle [DE=A1] [C], [D],	Intersection Check Vehicle(s) [DE]] [C] [D]
From (Approach) [B]	**Onto (Departure)** [B]		
Ramp	Major Arterial or Minor Arterial or Collector or Local	WB-65 [E] [F]	
Major Arterial or Minor Arterial or Collector or Local	Ramp	WB-65 [E] [F]	
Major Arterial or STH or Truck Route	Major Arterial or STH or Truck Route	WB-65 [E] [F]	
Major Arterial or STH or Truck Route	Minor Arterial	WB-40 SU-40 [F]	WB-65 [A2] [J]
Major Arterial or STH or Truck Route	Collector	WB-40 [F]	WB-65 [A2] [J]
Major Arterial or STH or Truck Route	Local	SU-30 [F]	WB-65 [A2] [J]
Minor Arterial	Major Arterial or STH or Truck Route	WB-40 SU-40 [F]	WB-65 [A2] [I]
Minor Arterial	Minor Arterial	WB-40 SU-40 [F]	WB-65 [A2] [H]
Minor Arterial	Collector	WB-40 [F]	WB-65 [A2] [H]
Minor Arterial	Local	SU-30 [F]	WB-40 [A2] [H] WB-65 [B2] [G], [I]
Collector	Major Arterial or STH or Truck Route	WB-40 [F]	WB-65 [B2] [G], [I]
Collector	Minor Arterial	WB-40 [F]	WB-65 [B2] [G], [I]
Collector	Collector	SU-30 [F]	WB-40 [A2] [H] WB-65 [B2] [G], [I]
Collector	Local	SU-30 [F]	WB-40 [A2] [H] WB-65 [B3] [G]
Local	Major Arterial or STH or Truck Route	SU-30 [F]	Wb-40 [B2] WB-65 [C2] [G]

Notes for Table 2.1:

A. Intersection geometrics shall be designed using turning templates or software such as AutoTURN or Auto Track. Submit the intersection plan with turning template overlay to the Regional Traffic Unit for review.

Coordinate with the Regional freight operations unit if there will be OSOW vehicles using an intersection.
See Table 2.2 for intersections where checking OSOW-ST and OSOW-MT vehicles is required.
See Figure 2.5 for WisDOT's interim policy on checking criteria for OSOW-ST and OSOW-MT vehicles at intersections.
See FDM 11-25-2.1.1.1 and FDM 11-25-2.1.1.2 for guidance on accommodating OSOW vehicles.
The OSOW Freight Network map is available at the following link,
http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf. See also FDM 11-25-1.4.

B. Functional Classification Systems Maps can be found on the dotnet at http://dotnet/dtim-bop/function/functionalmaps-rural.htm and at http://dotnet/dtim-bop/function/functionalmaps-urban.htm.
They can also be found at http://www.dot.wisconsin.gov/projects/planresources/functional.htm

Truck routes are shown on the "Wisconsin truck operators map", which is available at http://www.dot.wisconsin.gov/travel/maps/truck-routes.htm. See also, FDM 11-25-1.4.

C. See Figure 2.2, 2.3 and 2.4 for definitions and illustrations of Degree of Encroachment (DE)

D. A smaller Intersection Design Vehicle than shown in Table 2.1 may be appropriate at some locations but must be justified in the DSR. Conditions that might justify consideration of a smaller Intersection Design Vehicle include:

- Right-of-way is limited
- Trucks are prohibited on cross streets
- Current and projected Traffic counts show a small number of both the default Intersection Design Vehicle and vehicles that are larger than the default Intersection Design Vehicle (<1/day total) making the turn(s)
- Cross street volume is minimal (< 400 AADT) and the route is unlikely to be used as a detour route for a nearby higher volume roadway.

For 3R projects, the Intersection Design Vehicle may be site specific, if necessary, and may have a less restrictive turning radius than those for new construction and reconstruction projects. [31]

A larger Intersection Design Vehicle than shown in Table 2.1 may be appropriate at some locations but must be justified in the DSR. Conditions that might justify consideration of a larger Intersection Design Vehicle include:

- Current and projected Traffic counts show a significant number of vehicles that are larger than the default Intersection Design Vehicle making the turn(s)
- The encroachment of even a few large vehicles will cause significant traffic disruption

The following conditions apply if an Intersection Design Vehicle other than shown in Table 2.1 is used:

- Use the default Intersection Design Vehicle from Table 2.1 as an Intersection Check Vehicle, and verify that it can make the turn(s) - by encroaching onto other traffic lanes if necessary - without significantly disrupting traffic. For signalized intersections, if the default Intersection Design Vehicle is a WB-65, verify that the WB-65 can make the turn(s) with a DE=A2.
- The SU or school bus design vehicles are the smallest Intersection Design Vehicles used in the design of intersections on the STH. This design reflects that, even in residential areas, garbage trucks, delivery trucks, and school buses will be negotiating turns with some frequency.
- Verify that WB-65 trucks can physically make the turns at an intersection of two truck routes without backing up and without impacting curbs, parked cars, utility poles, mailboxes, traffic control devices, or any other obstructions, regardless of the selected Intersection Design Vehicle or allowable encroachment."

E. Check right turns with a WB-67 vehicle using DE=A1 - except encroaches onto curb flag

F. At signalized intersections, DE=A2 is acceptable for left turns from a single left turn lane if:

- Left turns are only allowed during protected phase, or
- There are no opposing vehicles (e.g., on the non-crossing leg of a T-intersection)

G. At signalized intersections, for the WB-65 Intersection Check Vehicle, use a preferred degree of encroachment (DE) = A2, with a minimum DE as shown.

H. A Degree of Encroachment (DE) = A3 may be acceptable for right turns by an Intersection Check Vehicle if there is a right-turn lane on the approach. This allows the vehicle to wait outside of the approach travel lane until traffic clears from the opposing lane on the departure leg. Use only if this is an infrequent occurrence and does not cause backups or other traffic disruptions.

I. At right-turn lanes with a contiguous bike lane between the turn lane and the travel lane, check the swept path of the WB-65 Intersection Check Vehicle to see if it is possible to avoid encroaching into the bike lane without significantly disrupting traffic or going outside of the roadway. Otherwise,

[31] (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-1.08(b), "Selection"

consider:

- accepting infrequent bike lane encroachments but consider a warning sign that right turning large trucks pull left before turning.
- If bike lane encroachment is frequent enough to be potentially dangerous, consider:
    - parking restrictions and/or a larger curb radius
    - Mark as a shared bike/right-turn lane instead of a separate bike lane and right-turn lane
    - Re-design to reduce or eliminate the conflict

Table 2.2 Intersections Where Checking OSOW-ST or OSOW-MT Vehicles is Required [A] [B] [C]

For Movement Made		OSOW Vehicles to Check
From (Approach Leg)	**To (Departure Leg)**	
FN - or non-FN with *KNOWN USE* by OSOW-ST vehicles - or Ramp	FN - or non-FN - with *KNOWN USE* by OSOW-ST vehicles - or Ramp	OSOW-ST & OSOW-MT check all applicable turning movements and thru movements
non-FN STH - or non-FN truck route	non-FN STH - or non-FN truck route	OSOW-MT check all applicable turning movements and thru movements

Notes for Table 2.2:

A. See Figure 2.5 for WisDOT's interim policy on checking criteria for OSOW-ST and OSOW-MT vehicles at intersections.

B. Coordinate with the Regional freight operations unit if there will be OSOW vehicles using an intersection. See FDM 11-25-2.1.1, 2.1.1.1 and 2.1.1.2 for additional guidance and requirements on checking OSOW-ST and OSOW-MT vehicles. Also,

C. The OSOW Freight Network map is available at the following link, http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf. See also, FDM 11-25-1.4.

   Truck routes are shown on the "Wisconsin truck operators map", which is available at http://www.dot.wisconsin.gov/travel/maps/truck-routes.htm. See also, FDM 11-25-1.4.

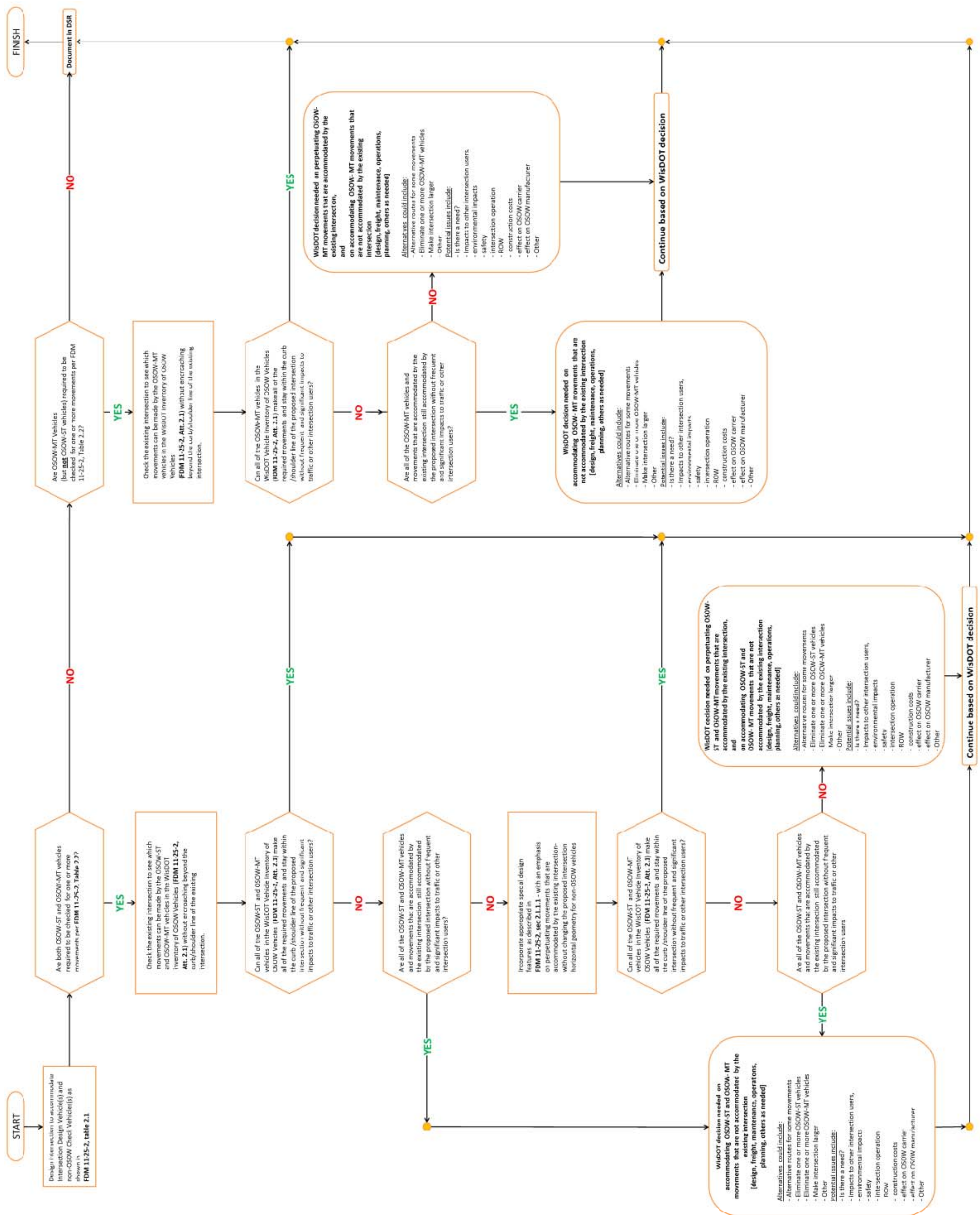


Figure 2.5 WisDOT's Interim Policy on Checking Criteria for OSOW-ST and OSOW-MT Vehicles at Intersections (included as Exhibit 2.1)

2.2 Physical and Functional Areas of an Intersection

Figure 2.6 shows the Physical and Functional Areas of an intersection.

The Physical Area of an Intersection is the pavement area where the intersecting roads coincide. The points of curvature of the intersection radii define the outer boundaries of the area[32].

The Functional Area of an Intersection includes the physical area, but also extends upstream and downstream from the physical area for a distance equal to the functional *length* of intersection, along all of the intersection roadways. It includes any auxiliary lanes and their associated channelization.

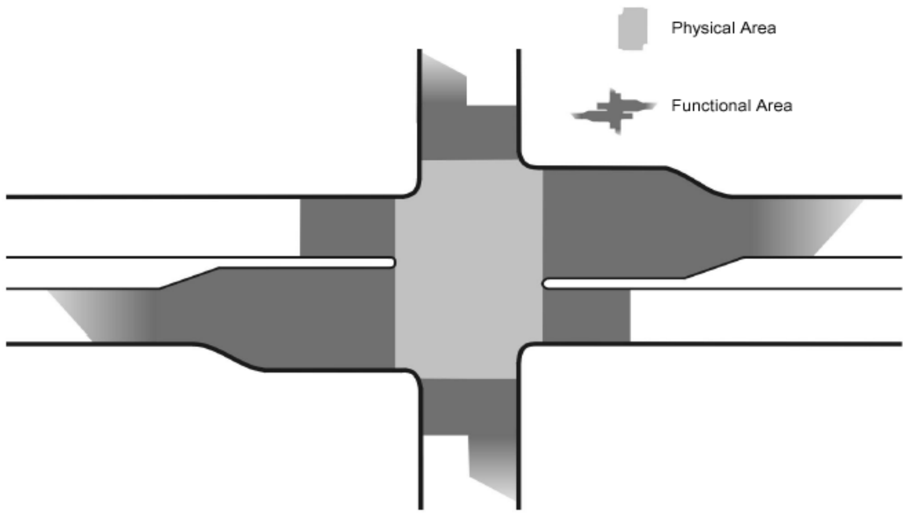


Figure 2.6 Physical and Functional Areas of an Intersection [33]

2.2.1 Downstream Functional Length of Intersection

The downstream functional length of intersection is the length of road downstream from an intersection - as measured from the sideroad edge of pavement on the downstream side of the intersection - needed to reduce conflicts between through traffic and vehicles entering and exiting the roadway. See Table 2.3 for the minimum requirements. See Figure 2.7 for illustrations of downstream functional length of intersection.

Table 2.3 Downstream Functional Length of Intersection Minimum Requirements

Traffic Control on Approaches (Upstream Thru Road Leg / Upstream Intersection Leg)	**Downstream Functional Length**
No control / No control or Stop Sign	Stopping Sight Distance (SSD) based on thru road design speed
Signalized / Signalized	
Roundabout / Roundabout	Stopping Sight Distance (SSD) based on 25 mph
Stop Sign / Stop Sign	
Stop Sign / No control and unchannelized turn	
No upstream leg (e.g., non-crossing leg of T-intersection) / Stop Sign	
No upstream leg (e.g., non-crossing leg of T-intersection) / No control and unchannelized turn	
Stop Sign / No control and channelized turn	Stopping Sight Distance (SSD) based on the greater of 25 mph or the speed of the channelized turn
No upstream leg (e.g., non-crossing leg of T-intersection) / No control and channelized turn	

[32] AASHTO GDHS 2004 (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp. 556-557)
[33] See TRB Access Management Manual (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 8-12, p 132 (TRB references from the "Access Management Manual" are reproduced with permission of the Transportation Research Board)

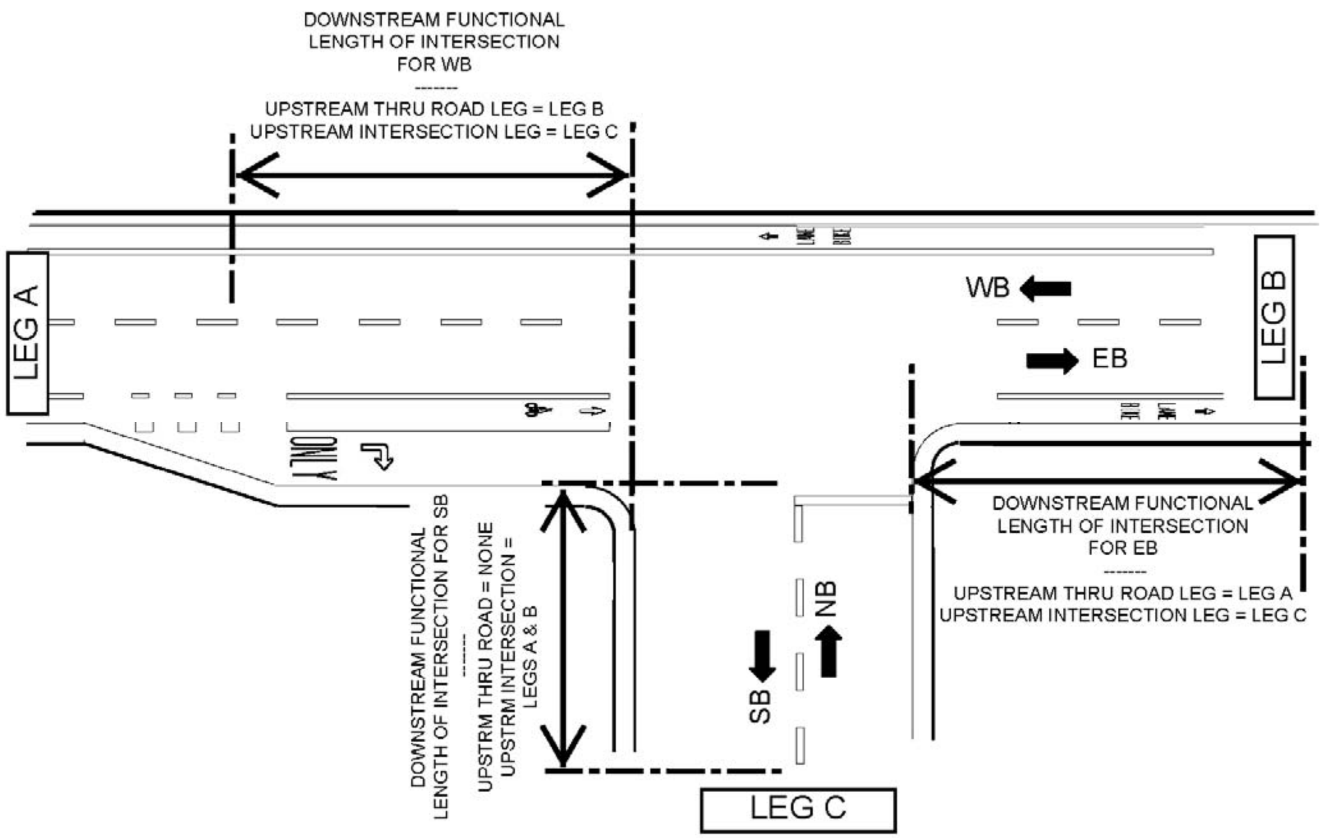


Figure 2.7 Downstream Functional Lengths of Intersection

The downstream functional length is also a parameter for access control in determining acceptable locations for median openings and minimum separation between private accesses and public road intersections (i.e., corner clearance - see FDM 11-25-2.5). Drivers making a turn at an intersection need adequate space to complete the maneuver before encountering vehicles turning into a downstream driveway. The left turn is the more complex maneuver because the driver is making it without positive guidance and must adjust speed, path, and direction.

2.2.2 Upstream Functional Length of Intersection

The upstream functional length of intersection is composed of four (4) elements as shown in Figure 2.8:

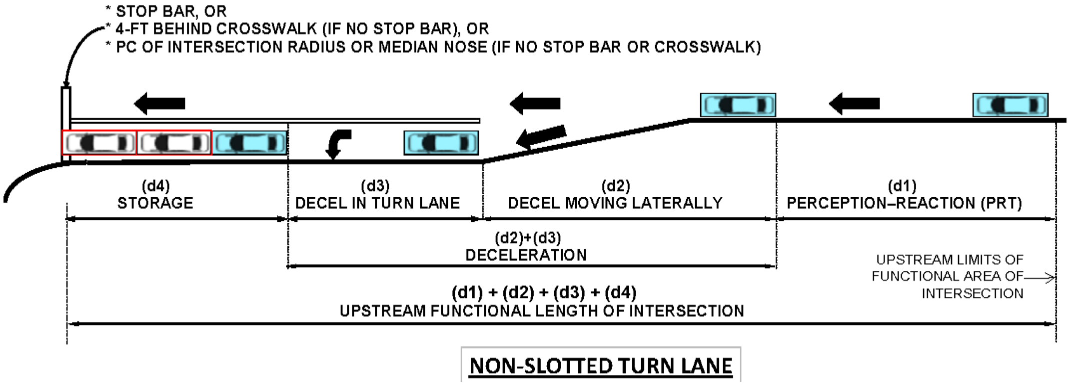
d1 = distance traveled at operating speed during the driver's perception–reaction time (PRT). See Table 2.4.

d2 = distance traveled as a vehicle clears a thru-lane and enters a turn lane by moving laterally 9-feet while braking. This is a more complex and demanding driving task than changing lanes only or braking only. See Table 2.4.
This element does not apply (i.e., d2=0-feet) to vehicles continuing in a thru-only lane or a shared turn-lane/thru-lane because there is no lateral movement).

d3 = distance traveled by vehicles in a turn lane while braking to a stop after a lateral shift from thru lane. For vehicles in a shared turn-lane/thru-lane or vehicles in a stopped/signalized thru-only lane, it is the distance traveled while braking to a stop after PRT. See Table 2.4.
This element does not apply (i.e., d3=0-feet) to vehicles continuing in an unstopped/unsignalized thru-only lane because there is no deceleration).

d4 = queue storage length. Typically, use Highway Capacity Manual (HCM) or other modeling software to compute the queue storage requirement, but other methods are available. Confer with the Region traffic engineer on the appropriate software and/or method. Note that the decelerating vehicle is the last vehicle in the queue. See Table 2.5 and Table 2.6 for queue storage requirements.
This element does not apply (i.e., d4=0-feet) to vehicles continuing in an unstopped/unsignalized thru-only lane because vehicles do not stop.

On the OSOW Freight Network (FN), the storage distance (d4) may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased storage distance would not be required at intersections with non-FN routes.



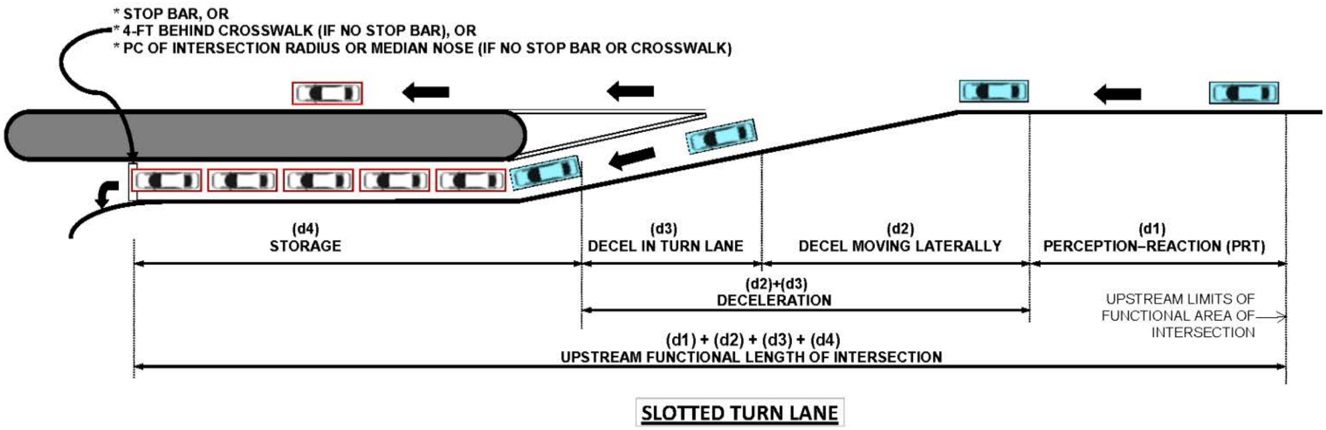


Figure 2.8 Upstream Functional Length of Intersection Elements[34]

[34] Adapted from (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-43, Figure 5-20

Table 2.4 Upstream Functional Length of Intersection Elements d1, d2, and d3 [A]

	Perception-Reaction Distance		Maneuver Distance		
	d1 (feet) **des** (min)		**d2** (feet) **des** (min)	**d3** (feet) **des** (min)	
Speed mph [B]	Rural [C] [E]	Urban / Suburban [C] [F]	[C] [G]	Turn lane [D] [H]	Thru lane [C] [I]
25	**90** (55)	**55** (35)	**75** (75)	**25** (25)	**100** (75)
30	**110** (65)	**65** (45)	**95** (95)	**75** (50)	**145** (105)
35	**130** (75)	**75** (50)	**110** (110)	**100** (75)	**195** (145)
40	**145** (90)	**90** (60)	**130** (130)	**150** (100)	**255** (185)
45	**165** (100)	**100** (65)	**150** (150)	**200** (150)	**325** (235)
50	**185** (110)	**110** (75)	**165** (165)	**250** (175)	**400** (290)
55	**200** (120)	**120** (80)	**185** (185)	**325** (225)	**485** (355)
60	**220** (130)	**130** (90)	**205** (205)	**400** (300)	**580** (420)
65	**240** (145)	**145** (95)	**225** (225)	**475** (350)	**680** (495)
70	**255** (155)	**155** (105)	**240** (240)	**575** (425)	**785** (575)

Notes for Table 2.4

A See Table 2.5 for guidance on Upstream Functional Length of Intersection element **d4** (Queue storage length)

B Use operating speed of travel lanes (except, not < 25 mph and not > design speed) - either as observed or as calculated using HCM or other appropriate method - Confer with the Region traffic engineer. Assume that free flow speed does not exceed Design Speed.

C All dimensions rounded to nearest 5-feet

D All dimensions rounded to nearest 25-feet

E Desirable distance based on a perception-reaction-time (PRT) of 2.5s.
Minimum distance based on a perception-reaction-time (PRT) of 1.5s.

F Desirable distance based on a perception-reaction-time (PRT) of 1.5s.
Minimum distance based on a perception-reaction-time (PRT) of 1.0s.

G Applies only to turn-lanes
The **d2** distance is based on an assumed deceleration rate of 5.8 fps^2 based , which is based on a vehicle moving laterally 9-feet at an assumed lateral shift rate of 3 to 4 fps, while reducing its speed by 10 mph.

A vehicle is assumed to have cleared the thru traffic lane when it has moved laterally 9-feet .The speed differential between the turning vehicle and following thru vehicles is 10 mph when the turning vehicle clears the thru traffic lane. [35]

H Applies only to turn-lanes
Distance to decelerate from [Speedminus10 mph] to [stop]
Desirable **d3** distance based on a deceleration rate of 6.7 fps^2, which is the observed 85^{th}-percentile rate.
Minimum **d3** distance based on a deceleration rate of 9.2 fps^2, which is the observed 50^{th}-percentile rate.

I Applies only to shared turn-lane/thru-lanes or stopped/signalized thru-only lanes
Distance to decelerate from [Speed] to [stop]
Desirable **d3** distance based on a deceleration rate of 6.7 fps2, which is the observed 85th-percentile rate.
Minimum **d3** distance based on a deceleration rate of 9.2 fps2, which is the observed 50th-percentile rate.

[35] Research shows that the crash rate is 3.3 times higher for a 20 mph speed differential than for a 10 mph speed differential; 23 times higher for a 30 mph speed differential; and 90 times higher for a 35 mph speed differential, as documented by Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-37).
Crashes resulting from excessive speed differential can occur up to several hundred feet from the intersection as well as at the intersection itself.

Table 2.5 Queue Storage (d4) for STH Intersections [36] [A] [B] [C]

Design Class	Approach Control	Thru-only Lanes des (min)	Left Turn des (min)	Right Turn des (min)
Rural A2, A3	**No control**	no storage required	**greater of 90th pctl or 4-veh** (greater of 90th pctl or 2-veh	**90th pctl**
	Stop Sign	**greater of 90th pctl or 4-vehicles** (greater of 90th pctl or 2-vehicles)		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 4-vehicles** (greater of 95th pctl or 2-vehicles)	
Rural other	**No control**	no storage required	**greater of 90th pctl or 2-vehicles**	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles**		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** (greater of 90th pctl or 2-vehicles)	
Urban transitional/high-speed UA2, UA3	**No control**	no storage required	**greater of 90th pctl or 4- veh** (greater of 90th pctl or 2- veh	**90th pctl**
	Stop Sign	**greater of 90th pctl or 4-vehicles** (greater of 90th pctl or 2-vehicles)		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 4-vehicles** (greater of 95th pctl or 2-vehicles	
Urban transitional/high-speed other	**No control**	no storage required	**greater of 90th pctl or 2-vehicles**	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles**		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** (greater of 90th pctl or 2-vehicles)	
Urban low-speed 3, 4, 5	**No control**	no storage required	**greater of 90ctl or 4- veh** (greater of 90th pctl or 2- veh	**90th pctl**
	Stop Sign	**greater of 90ctl or 4 vehicles** [D] (greater of 90th pctl or 2-vehicles) [D]		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95ctl or *4 vehicles** [D] (greater of 90th pctl or *2-vehicles) [D]	
Urban low-speed other	**No control**	no storage required	**greater of 90th pctl or 2 vehicles** [D]	**90th pctl**
	Stop Sign	**greater of 90th pctl or 2-vehicles** [D] (greater of 85th pctl or 2-vehicles) [D]		
	Signalized	50th pctl (Check 95th pctl for backup into adjacent intersection, etc.)	**greater of 95th pctl or 2-vehicles** [D] (greater of 90th pctl or 2 vehicles) [D]	
all	**Roundabout**	see FDM 11-26		

Notes for Table 2.5

A pctl = percentile

B Assume vehicle length = 25-feet

C On the OSOW Freight Network (FN), storage distance (d4) may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased storage distance is not be required at intersections with non- FN routes.

D one (1) vehicle if peak turning volume < 20 vph

[36] Adapted from Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf., pp.23-25); see also Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. ITE, 2006., pp. 5-50 to 5-53)

An intersection approach may have a different upstream functional length for the thru lane(s), left-turn bay, and right-turn bay because of different queue storage requirements for those lanes. Each lane of a multi-lane approach can have a different upstream functional length. The upstream functional length for a thru lane is the longer of the functional length calculated for the thru lane and the functional length(s) calculated for the turn bay(s) adjacent to that thru lane.

The upstream functional length of intersection is not a static dimension, particularly on urban roads. It can vary because operating speeds and queue storage requirements vary during the course of a day. For example, during peak conditions, the queue storage requirement (**d4**) might be longer because there are more turning vehicles; but the PRT (**d1**) and maneuver distances (**d2** & **d3**) might be shorter because operating speeds are lower. The opposite might be true during non-peak conditions.

Use the upstream functional length of intersection to design and evaluate turn bay lengths (see Table 2.5, "Turn Bays" for additional guidance).

In addition, upstream functional length of intersection is a parameter for access control when determining acceptable locations for median openings and minimum separation between private accesses and public road intersections (i.e., corner clearance). See the sections below on "Median Opening Locations" and "Driveways and Corner Clearance".

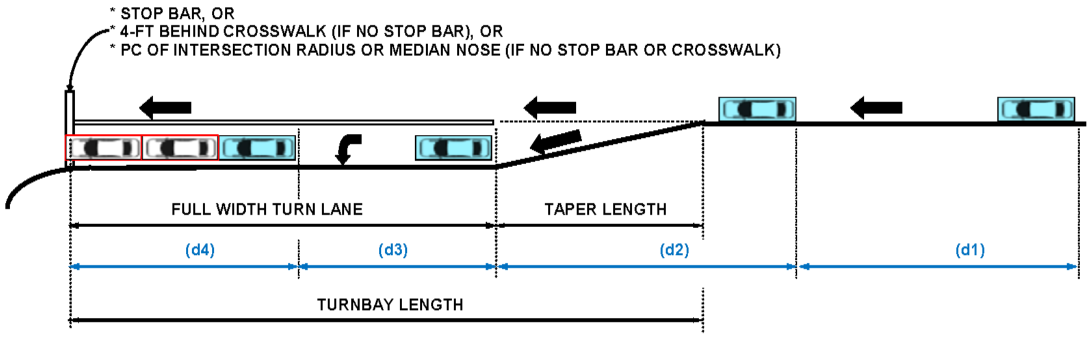
2.3 Turn Bays

Turn bay length includes both the approach taper and the full width turn lane (see Figure 2.9). Providing adequate turn bay length is important because it minimizes deceleration in the thru travel lanes by turning vehicles [37], and it reduces the probability of "spillback" into the travel lane by queued turning vehicles.

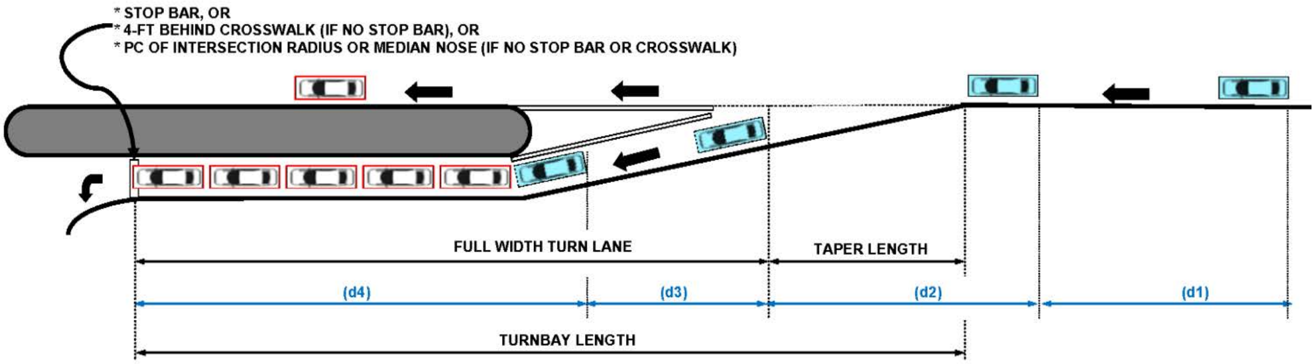
Use the following guidance for determining turn bay length:

- Use the upstream functional length to design and evaluate turn bay lengths (see Figure 2.9 for the correlation of Upstream Functional Length of Intersection and Turn Bay elements).
- Calculate for both the peak and non-peak conditions and use the longer of the two to determine the length of turn bay.
  - See Table 2.4 for functional length elements **d1**, **d2**, and **d3** (i.e., PRT and deceleration)
  - See Table 2.5 for functional length element **d4** (i.e., queue storage);
  - See Table 2.6 for full-width turn lane lengths
  - See Attachment 2.2 for turn bay taper lengths.
- If possible, provide a turn bay length that meets desirable criteria. A design based on desirable criteria will maximize the safety, operational efficiency and capacity of an intersection approach – and provide a margin of error when conditions exceed design assumptions.
- If it is not possible to meet desirable criteria because of physical constraints or existing development then, if possible, provide a turn bay length that exceeds minimum criteria.
- If it is not possible because of physical constraints or existing development to exceed minimum criteria then provide a turn bay length that meets minimum criteria.
- If it is not possible to meet minimum criteria, look at removing or relocating the physical constraint. If that is not possible, it may be necessary to close the median opening or restrict movements if it is not possible to provide a proper left turn lane. As a last resort, with the approval of the Regions access coordinator and traffic engineer, provide a shorter turn bay rather than no turn bay at all. Try to provide enough queue storage to minimize spillback into the thru lanes.

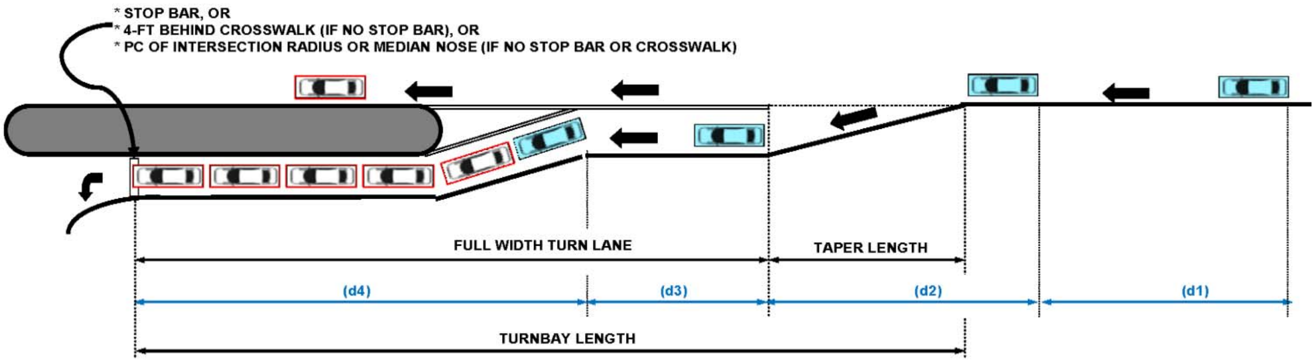
[37] As documented by Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-37, Table 5-12): The crash rate is 3.3 times higher for a 20 mph speed differential vs. a 10 mph speed differential; 23 times higher for a 30 mph speed differential vs. a 10 mph speed differential; and 90 times higher for a 35 mph speed differential vs. a 10 mph speed differential



NON-SLOTTED TURN LANE



SLOTTED TURN LANE



SLOTTED TURN LANE - ALTERNATE

Figure 2.9 Turn Bay Elements and Correlation with Upstream Functional Length of Intersection

Table 2.6 Full-Width Turn-Lane Length for Urban Streets and Low Speed Rural [A] [38]

Approach Control	Left Turn Lane		Right Turn Lane	
	Rural	Urban	Rural	Urban
No control (i.e., un-stopped)	**d3+d4** [B] [C] [D]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D]	**d3+d4** [B] [C] [D]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D]
Stop Sign	**d4** [B] [C] [D] [E] [F]			
Signalized	**d3+d4** [B] [C] [D] [F]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D] [F]	**d3+d4** [B] [C] [D] [F]	Posted speed<=30 mph **d3+d4** (d4) Posted Speed>30 mph **d3+d4** [B] [C] [D] [F]

Notes

A See FDM 11-25 Attachment 1.1 for guidance on high-speed rural turn lanes

B On the OSOW priority network, full-width turn lane length may need to be adjusted to accommodate one OSOW vehicle, depending on load frequency. Increased length would not be required at intersections on OSOW secondary routes.

C See FDM 11-25-2.2.2, “Upstream Functional Length of Intersection” for definitions of dimensions **d3** and **d4**.

See Table 2.4 for **d3** dimension_ see Table 2.5, for **d4** dimension.

D **Vertical Alignment:** A crest vertical curve can hide the beginning of a turn bay. Avoid this by extending the full width turn-lane so that the turn lane is perceptible from the PRT distance. Do this by lengthening the full width turn-lane rather than lengthening the taper.

E Both thru and turning vehicles decelerate on the approach to a stop sign, which minimizes the potential speed differential.

F **Length of queue in the adjacent thru lane:** The thru lane queue can sometimes block entry into a turn bay. This can have a negative effect on the operation and capacity of the intersection if it occurs on a regular basis. Avoid this by extending the length of full-width turn-lane so that it is at least as long as the longest expected queue in the adjacent thru lane. (This is normally more critical for a left turn bay than a right turn bay).

2.3.1 Left Turn Lanes

See FDM 11-25-5 for additional guidance on left-turn lanes.

2.3.2 Right Turn Lanes

See FDM 11-25-10 for additional guidance on right-turn lanes.

2.4 Taper Design

Tapers commonly used around at-grade intersections can be classified as follows.

- Shifting taper
- Merge taper
- Add lane taper
- Turn bay taper (see FDM 11-25-2.3)

[38] Adapted from (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf.

- Shoulder taper

See Attachment 2.2 for descriptions of these features as well as guidance for designing them. Much of the guidance in Attachment 2.2 comes from the FHWA MUTCD[39] and the AASHTO GDHS 2004[40].

2.4.1 Lane Reduction at Intersection

It is more desirable to continue a full-width thru lane beyond an intersection and then terminate the lane with a lane-drop taper (i.e., merging taper) than to terminate the lane at the intersection as a turn-only lane (i.e., “trap” lane).

The table in Attachment 2.2 shows both the desirable and minimum length of tangent section that is to precede a merging taper on the downstream side of an intersection. The desirable distance provides enough room for placing two signs (W9-1R and W4-2R) upstream from the merge point. The minimum distance provides enough room for placing only one sign (W4-2R).

The minimum tangent length comes from the Condition ‘A’ column of Table 2C-4 of the Wisconsin Supplement to the MUTCD (available on both the dotnet and the extranet at http://www.dot.wisconsin.gov/business/engrserv/wmutcd.htm) and represents the distance between the W4-2R sign and the start of the merge taper. This distance varies according to the posted speed of the road. The desirable tangent length equals the minimum tangent length plus 200-feet.

WisDOT’s standard practice is to provide for two signs in advance of a merging taper. The first sign is the W9-1R and is located at the desirable distance upstream from the start of the merging taper - either on the signal pole on the downstream side of the intersection or on a separate post just beyond a non-signalized intersection. The second sign (W4-2R) is located at the minimum distance upstream from the start of the merging taper and 200 ft downstream from the first sign. For example, at a posted speed of 55 mph, a W9-1R sign is located 950-feet ahead of the start of the merging taper; and a W4-2R sign is located 750-feet ahead of the start of the merging taper.

Consider a longer tangent distance if the approach roadway has less than the minimum Stopping Sight Distance (SSD) required by FDM 11-10-5.

2.5 Corner Clearance to Driveways

Traffic conflicts occur when the paths of vehicles intersect and may involve merging, diverging, stopping, weaving, or crossing movements. Each conflict point is a potential collision. Each new access point introduces conflicts and friction into the traffic stream. As conflicts increase, driving conditions become more complex, drivers are more likely to make mistakes, crash potential increases, and the resulting friction translates into longer travel times and greater delay. Conversely, simplifying the driving task contributes to improved traffic operations and reduces collisions. Separating conflict areas helps to simplify the driving task and contributes to improved traffic operations and safety. [41]

The functional area of an intersection is the critical area where motorists are responding to the intersection, decelerating, and maneuvering into the appropriate lane to stop or complete a turn. Access connections too close to intersections can cause serious traffic conflicts that impair the function of the affected facilities. Drivers need sufficient time to address one potential set of conflicts before facing another.

Driveways are, in effect, intersections. Their design and location merit special consideration because crashes are disproportionately higher at driveways. Ideally, driveways are not located within the functional area of an intersection or in the influence area of an adjacent driveway”[42]

“Corner clearance represents the distance that is provided between an intersection and the nearest driveway.”[43] Marginal corner clearance (Figure 2.10) is the distance between an intersection and the nearest driveway along the same side of the highway. Median corner clearance (Figure 2.11) is the distance between an intersection and the nearest median opening for a driveway. See FDM 11-25-20.4 for median opening location criteria and requirements.

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[39] (*14) Manual on Uniform Traffic Control Devices*. Federal Highway Administration, 2009., chapters 3 & 6
[40] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.715-716)
[41] (*11)Access Management Manual*. Transportation Research Board, 2003., pp.8, 143
[42] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p.729)
[43] (*11)Access Management Manual*. Transportation Research Board, 2003., p.155)

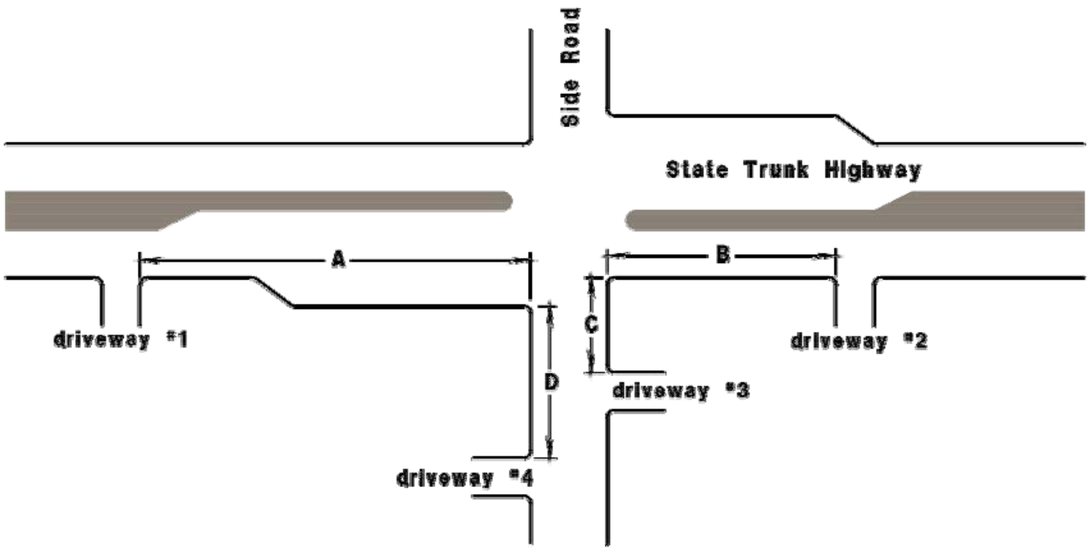

Figure 2.10 Intersection Marginal Corner Clearances[44] (See [Table 2.7](#))

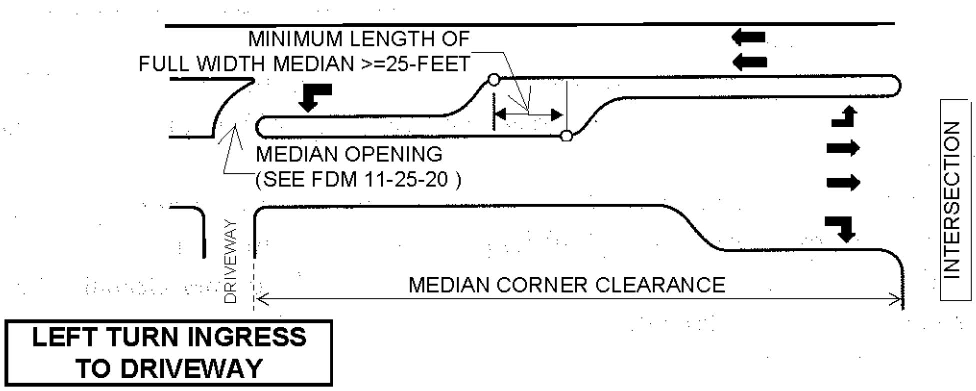

Figure 2.11 Intersection Median Corner Clearances[45]

Inadequate corner clearances can result in traffic operation, safety, and capacity problems. These problems can be caused by blocked driveway ingress and egress, conflicting and confusing turns at intersections, insufficient weaving distances, and backups from a downstream driveway into an intersection.

Use the following guidance for corner clearance on STH's:

1. If possible, provide a driveway on corner parcels from the side road instead of from the STH. This requires safe and convenient alternative access and reasonable internal site circulation
2. If it is necessary to provide a driveway from the STH, then limit a corner parcel to one (1) driveway on the STH. If possible, locate this driveway at or beyond the corner clearance requirement shown in Table 2.7. If the corner parcel has insufficient frontage, then it may be possible to accomplish this by consolidating driveways with an adjacent property. Follow the guidance in FDM 11-20 Attachment 10.1 for driveway placement near a property line.
3. If it is necessary to provide driveway access from the STH and it is not possible to construct the driveway at or beyond the corner clearance requirement shown in Table 2.7, then limit a corner parcel to one (1) driveway on the STH that meets all of the following conditions:
   - Locate the driveway as far from the intersection as possible. Follow the guidance in FDM 11-20,

[44] (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 9-10, p 157 (TRB references from the "Access Management Manual" are reproduced with permission of the Transportation Research Board)
[45] Adapted from Stover & Koepke (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.6-24 to 6-35 and Figure 6-19). **© 2012 Institute of Transportation Engineers, 1627 Eye Street, NW, Suite 600, Washington, DC 20006 USA, www.ite.org. Used by permission.**

Attachment 10.1 for driveway placement near a property line. Always consider consolidating driveways to increase the corner clearance distance.

- Do not allow left-turn ingress and egress at driveways within the functional area of intersection on the STH, except as provided in Table 20.1. Provide a physical (nontraversable) median on the STH to preclude left turns into or out of driveways. For divided highways, this means not allowing a median opening for a driveway within the functional area of intersection, except as provided in Table 20.1. For undivided highways, this means providing short sections of a median divider and/or adopting a driveway design that discourages or prevents left turn maneuvers.
- Do not locate a driveway inside a right-turn bay unless all of the following apply:
  - Alternative access is not possible,
  - The driveway is low-volume (<15 vpd),
  - A non-traversable median prevents left turns into or out of the driveway,
  - Vehicles cannot maneuver into the left-turn lane from the driveway, and
  - The successive separate right-turn bays would either be undesirably short and/or too close together.
- If possible, restrict a nearside driveway to right in if it is within the queue storage limits of the downstream intersection.
- If possible, restrict a far-side driveway to right out if it is closer than stopping sight distance from the upstream intersection.
- Do not locate a driveway within the physical area of the intersection (see Figure 2.6). Provide at least 25-feet between the PC of the intersection curb radius and the PC of the driveway curb radius.
- Do not locate a nearside driveway at or downstream from the stop bar for the downstream intersection. Provide at least 25-feet between the stop bar and the PC of the driveway curb radius.
- Do not locate a driveway within the limits of a legal crosswalk, or within the limits of a curb ramp for a crosswalk.

4. If possible, relocate the driveway if joint or alternate access becomes available that meets or exceeds corner clearance requirements.

Table 2.7 Marginal Corner Clearance Distances

<table>
<tr><th>Corner Clearance Description</th><th>Urban</th><th>Rural</th></tr>
<tr><td>A -
Approach (nearside) on the STH</td><td>The upstream functional length for the STH)(see FDM 11-25-2.2.2)</td><td>Desirable
The greater of the upstream functional length of intersection for the STH (see FDM 11-25-2.2.2) or the distance for private intersections from FDM 11-5 Attachment 5.1
Minimum
The distance for private intersections from FDM 11-5 Attachment 5.1</td></tr>
<tr><td>B -
Departure (farside) on STH</td><td>Desirable
The greater of the downstream functional length of intersection for the STH (see FDM 11-25-2.2.1) or the upstream functional length for the proposed driveway Minimum
The downstream functional length of intersection for the STH (see FDM 11-25-2.2.1)</td><td>Desirable
The greater of the downstream functional length of intersection for the STH, or the distance for private intersections from FDM 11-5 Attachment 5.1
Minimum
The distance for private intersections from FDM 11-5 Attachment 5.1</td></tr>
<tr><td>C -
Approach (nearside) on the side road</td><td colspan="2">STH side road
The corner clearance requirement is equal to that of corner clearance “A.”
Non-STH side road
Desirable
the upstream functional length of intersection for the side road
Minimum
If the observed or estimated queue of vehicles on a crossroad approach will frequently block a driveway entrance (as shown in Figure 2.12), then provide a corner clearance that is greater than the longest expected queue. This will reduce the probability of a backup into the intersection by vehicles making a left turn into the driveway. For additional guidance, see the TRB Access Management Manual starting on p. 155[46] and also ITE’s Transportation and Land Development starting on p. 6-28[47].
if the above corner clearances aren’t possible, apply the conditions of requirement 3 from the section, “Corner clearances on STHs”</td></tr>
<tr><td>D -
Departure (farside) on the side road</td><td colspan="2">STH side road
The corner clearance requirement is equal to that of corner clearance “B.”
Non-STH side road
Drivers making a turn onto a sideroad from a STH need adequate space to complete the maneuver before encountering vehicles turning into a downstream driveway on the side road. The left turn from the STH is the more complex maneuver because the driver is making it without positive guidance and must adjust speed, path, and direction. For additional guidance, see the TRB Access Management Manual starting on p. 155 and also ITE’s Transportation and Land Development starting on p. 6-32.
Desirable
The greater of the downstream functional length of intersection for the side road (see FDM 11-25-2.2.1) or the upstream functional length for the proposed driveway
Minimum
The downstream functional length of intersection for the side road (see FDM 11-25-2.2.1)
if the above corner clearances aren’t possible, apply the conditions of requirement 3 from the section, “Corner clearances on STH’s”.</td></tr>
</table>

2.5.1 Corner Clearance for non-STH roads

WisDOT’s main concern with driveways on non-STH side roads is that they do not adversely affect the STH roadway (see Figure 2.12). However, WisDOT may not have the same degree of control on non-STH side roads as it does on the STH, and may need to work with the local jurisdiction to achieve adequate corner clearances.

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[46] *(11)Access Management Manual*. Transportation Research Board, 2003.
[47] *(12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006.

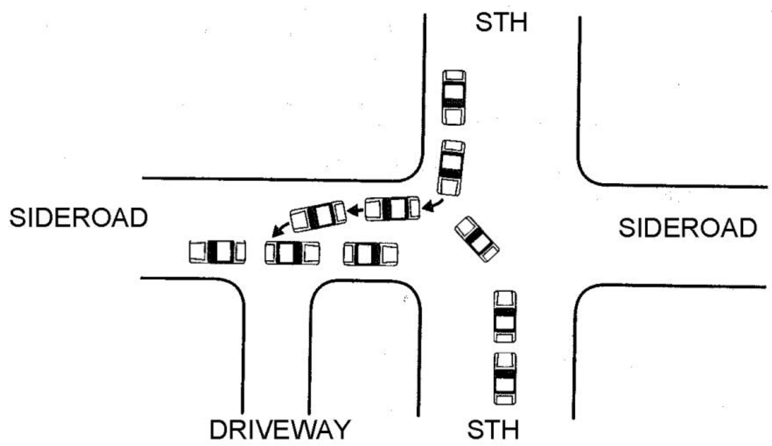

Figure 2.12 Inadequate Corner Clearance on Sideroad[48]

2.6 Intersection Vertical Alignment

See pp.582 and 279-282 of the 2004 GDHS[49].

If possible and practical, avoid grades in excess of 3% within the intersection area and on the portion of approaches where vehicles are required to stop because this complicates intersection design. Desirably, grades will be flatter than the maximum values allowed (see FDM 11-10-5.4.1 and Attachment 5.3).

On the OSOW Freight Network, check the roadway profile to avoid abrupt grade transitions that may affect OSOW-ST vehicles with low ground clearance. OSOW-ST vehicles with very low ground clearance can hang up on the roadway crown or the rollover between a superelevated section and a side road profile at intersections.

Additionally, on the OSOW Freight Network, some loads on OSOW-ST vehicles are susceptible to torsion or twisting forces that can exceed the torsional shear capacity of a blade, beam, or concrete member. If possible, design the vertical alignment and cross slopes in the intersection area to help avoid excessive shear forces created by torsion forces as the OSOW-ST Vehicle maneuvers the intersection.

Avoid locating intersections just beyond the crest of vertical curves.

2.7 Intersection Sight Distance

For information about intersection sight distance, refer to FDM 11-10-5.

2.8 Angle of Intersection[50]

It is preferable for intersecting streets to meet at an angle as close to 90°as possible. On the OSOW Freight Network, it is preferable for roadways to intersect at an angle as close to 90° as possible, thus reducing the impact of those vehicles with a large turning radius.

It may be necessary to shift the intersection and to realign part of the sideroad in order to improve the angle of intersection. This usually requires inserting a horizontal curve on the sideroad in close proximity to the intersection. See FDM 11-10-5.1.1.4, “Sight Distance on a Stop Sign Controlled Approach” and FDM 11-10-5.2.2, “Horizontal Curve on a Stop Sign Controlled Approach”.

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[48] Adapted from (*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., Figure 6-20 on p. 6-30. © 2012 Institute of Transportation Engineers, 1627 Eye Street, NW, Suite 600, Washington, DC 20006 USA, www.ite.org. Used by permission.

[49] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[50] (*15)* Intersection Angle Geometry and the Driver's Field of View. In *Transportation Research Record 1612: Highway Geometric Design Issues* TRB, National Research Council, 1998, pp.10-16.,
(16) Highway Design Handbook for Older Drivers and Pedestrians. FHWA-RD-01-103*.* Federal Highway Administration Turner-Fairbank Highway Research Center, 2001. http://www.tfhrc.gov/humanfac/01103/coverfront.htm.
(17) Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians. FHWA-RD-01-051*.* Federal Highway Administration, 2001. http://www.tfhrc.gov/humanfac/01105/cover.htm.
(18) Older Driver Highway Design Handbook [ch.1 - Intersections (At-Grade)]. FHWA-RD-97-135*.* Federal Highway Administration, 1998. http://www.tfhrc.gov/safety/pubs/97135/index.htm#intro.

2.8.1 Angle of Intersection for New Intersections

The following applies to new intersections on all projects

2.8.1.1 Intersection on Tangent or on Outside of Curve:

- Desirable: between 75° and 105°
- Minimum: 70°
- Maximum: 110°

2.8.1.2 Intersection on Inside of Curve

Table 2.8 Angle of Intersection for Intersection on Inside of Curve

Road	Radius (ft)	Desirable angle	Minimum angle	Maximum angle
High Speed and Transitional	>6000	between 75° and 105°	70°	110°
	4000-6000	between 80° and 100°	75°	105°
	<4000	between 85° and 95°	80°	100°
Low Speed	>3000	between 75° and 105°	70°	110°
	2000-3000	between 80° and 100°	75°	105°
	<2000	between 85° and 95°	80°	100°

2.8.2 Angle of Intersection for Existing Intersections on New Construction and Reconstruction Projects

2.8.2.1 Intersection on Tangent or on Outside of Curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than 65°or greater than 115°.

2.8.2.2 Intersection on inside of curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than the minimum angle for new construction by 5° or more, or
- The existing angle is greater than the maximum angle for new construction by 5° or more.

2.8.3 Angle of Intersection for Existing Intersections on 3R Projects

2.8.3.1 Intersection on Tangent or on Outside of Curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than 60°or greater than 120°.

2.8.3.2 Intersection on Inside of Curve

Improve the intersection angle using the guidelines for NEW intersections if the existing intersection meets any of the following conditions:

- The existing angle is less than minimum or greater than maximum angle for NEW intersections and the angle is contributing to intersection crashes, or
- The existing angle is less than the minimum angle for new construction by 10° or more, or
- The existing angle is greater than the maximum angle for new construction by 10° or more.

2.9 Intersections on Curves

Intersections on curves of any facility are problematic and are discouraged for the following reasons:

- Drivers have more difficulty judging the speed of vehicles approaching on a curve than on a tangent.
- Superelevation complicates the intersection geometry.
- More right-of-way may be required to ensure adequate intersection sight distance (ISD), particularly on the inside of curves where the line of sight for intersection sight distance may be a considerable distance outside the roadway.
- Intersections on the inside of a curve require drivers on the side road to turn their heads more to see approaching traffic. This can be difficult for some drivers, including older drivers.

If an intersection must be on a curve, then try to use a flatter radius curve and to make the intersection as close to radial as possible. For example, on high speed roads, using a curve that requires a superelevation of 3% or less will make it easier to match into the side road profile and to transition the cross slope on auxiliary lanes. It will also keep the ISD line of sight closer to the roadway. A radial intersection in combination with a flat radius will reduce the amount drivers have to turn their heads to see approaching traffic.

Intersections on curves of high-speed (posted speed greater than 55 mph) expressways require additional design considerations. Crash history shows that there is no difference in whether the side road intersection approaches the expressway from the outside or the inside of the curve. Providing more than the minimum intersection sight distance at these intersections appears to have no impact on the number or severity of crashes. If there appears to be no alternative to designing an intersection on a curve then provide a wide median. If a wide median for intersections on curves is not possible then it is important to restrict intersection movement by closing the median or at least not allowing side road traffic to turn left onto the expressway.

2.10 References

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[51] [Aug 17, 2004 email from Javy Awan, Director of Publications, Transportation Research Board] TRB references are reproduced with permission of the Transportation Research Board, From Access Management Manual, Transportation Research Board, National Research Council, Washington, D.C., 2003

[52] [Dec 5, 2012 email and attached letter from Zach Pleasant, Information Services Director, ITE] The Institute of Transportation Engineers grants permission to use Figures 6-19, P6-27 and 6-20, P6-30 from Transportation and Land Development, 2nd Edition for the Wisconsin DOT's Facilities Development Manual (FDM 11-25). Please know that this is a one-time, one-use agreement, and any other use of this material or any other resource of ITE must be requested and approved in writing.
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LIST OF ATTACHMENTS

Attachment 2.1	WisDOT Vehicle Inventory of Oversized Overweight (OSOW) Vehicles
Attachment 2.2	Taper Length Criteria
Exhibit 2.1	WisDOT Interim Policy on Checking Criteria for OSOW-ST and OSOW-MT Vehicles at Intersections

FDM 11-25-3 Intersection Control Evaluation *October 22, 2012*

3.1 Intersection Control Evaluation (ICE)

There are increasing types of intersections that, combined with traffic control, may be considered for addressing traffic delay and safety concerns. To select the appropriate intersection configuration and traffic control, the region shall perform an Intersection Control Evaluation (ICE) at all intersections on the State Trunk Highway (STH) that are identified as potentially benefiting from an alternative traffic control or intersection type.

The purpose of the ICE worksheet is to document the analysis (i.e. technical & financial) that assists the Region in determining a recommended alternative. The goal is to select the optimal control, lane configuration, and type of intersection based on an objective analysis of the existing conditions and future needs. An ICE worksheet shall be prepared by, or under the supervision of, a professional engineer, registered in Wisconsin, with experience in traffic engineering operations.

Typically, intersection improvement projects are developed as a portion of a much larger project or as a safety or capacity driven project at a specific location. For smaller projects, the identified need to evaluate alternative traffic control or intersection types is usually the major component of the project and the ICE worksheet will have a major impact in the development process. In contrast, as part of a larger project, intersection control treatments may be a much smaller component and other decisions in the project development process will have more impact on the ICE. Therefore, it is important to emphasize that the ICE must occur as early as practical in the process so that the project proceeds smoothly.

3.1.1 Types of Projects

Projects designed and constructed with federal or state funding must comply with the ICE process when considering intersection traffic control as discussed above. These include:

- Improvement Projects (3R, 4R)
- Majors
- Highway Safety Improvement Program (HSIP)
- Traffic Impact Analysis (TIA)
- Safe Routes To School (SRTS)
- Congestion Mitigation and Air Quality (CMAQ)
- Local projects

The ICE process is the same for projects identified by WisDOT, counties, municipalities, or local units of government that are interested in receiving federal or state funds on any of the projects identified above.

3.1.2 Guidance and Criteria for Intersection Control Types

1. Stop Sign Control

   An intersection may have One-Way or Two-Way Stop Control (OWSC or TWSC)[53], or it may have All-Way Stop Control (AWSC). The one-way or two-way stop control is most common and requires traffic to stop on the minor road connection(s) to a major highway. Typically, one-way or two-way stop control is the existing traffic control alternative in the ICE study.

   Consider All-Way Stop Control if warrants are met and AWSC is shown to improve the safety of the intersection. Refer to Traffic Guidelines Manual in section 13-26-5 found at (https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/tgm/index.shtm) for criteria that combines WisDOT and MUTCD considerations.

2. Signal Control

   Consider signal control if certain traffic warrants are met as discussed in the MUTCD - Section 4C and the Traffic Signal Design Manual (TSDM) Chapter 2 (https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/tsdm/ch02.shtm). Also, see the TSDM for design, capacity, and operational guidance for signal control.

3. Roundabout Control

   The modern roundabout is considered as a traffic control alternative when the minimum vehicular volumes that warrant all-way stop control or a traffic signal are met. There may also be situations where it may be appropriate to consider a roundabout where an intersection may have unique safety or geometric concerns.

   Multilane Roundabouts are typically safer than conventional alternatives, particularly with respect to injury and fatal crashes but, this does not mean they are without safety challenges. One of these challenges is getting drivers to select and stay in their proper lanes as they navigate the roundabout. Some drivers take the fastest path through roundabouts by entering in the right lane, crossing to the center lane midway through the circulatory roadway, and then crossing back into the right lane at the exit, generally during lower traffic conditions. This driver behavior creates a risk of increased sideswipe crashes. Another challenge for both safety and operational efficiency is that drivers sometimes have difficulty interpreting lane-control arrows and signage in the roundabout context. Even with these concerns, engineers have begun to introduce three-lane roundabouts where design year peak hour traffic cannot be accommodated in one or two circulating lanes. The use of three-lanes in any part of the circulatory roadway raises the concern that low comprehension and compliance could be more significant when compared to two-lane roundabouts. Therefore, whenever the preferred traffic control alternative for a particular intersection or interchange is a three-lane roundabout the Bureau of Traffic Operations (BTO) State Traffic Engineer, in conjunction with the Bureau of Project Development (BPD) Roadway Standards Chief, *shall* approve the roundabout as the preferred traffic control alternative. If the roundabout alternative includes a spiral design, this needs to be indicated in the ICE Worksheet.

   Careful consideration and coordination among regional traffic engineers and designers as well as local entities must be part of the project development process when considering a roundabout. Refer to section 3.3 of NCHRP Report 672 (http://www.trb.org/Main/Blurbs/164470.aspx) for considerations in selecting a roundabout as an alternative. Refer to FDM 11-26 for design and operational guidance on roundabouts.

4. Reduced-Conflict Intersections

   Traffic Engineers and designers have additional options in intersection/interchange design that combined with traffic control may be appropriate for a given situation. Examples include, but are not limited to, J-turn intersections, continuous flow intersections (CFI), jughandle intersections, echelon interchanges, single point diamond interchanges (SPI), diverging diamond interchanges (DDIs), and others. These designs may have advantages over traditional intersection types, depending on the existing and future safety and operational concerns.

   Some of these intersection types are adaptable for only one type of intersection control. It is still possible to compare alternative intersection control types but intersection geometry may be different for each control type. The ICE could also compare different intersection types with the same intersection control. For some reduced-conflict intersection/interchange, microsimulation may be

[53] One-Way Stop Control (OWSC) applies to Tee-Intersections; Two-way Stop Control (TWSC) applies to 4-legged intersections

necessary to perform the operational analysis. Refer to FDM 11-25-3.7 for a description of approved microsimulation software's and their appropriate use.

The Department recognizes the lack of design and analysis standards for reduced-conflict intersections, but this should not discourage the selection of these types of designs as the preferred alternative. The expected future demands on many facilities, as well as the benefits reduced conflict intersections may bring for a particular location, could favor the implementation of these intersection types. Therefore, whenever the preferred traffic control alternative for a particular intersection or interchange is a reduced-conflict intersection/interchange the Bureau of Traffic Operations (BTO) State Traffic Engineer, in conjunction with the Bureau of Project Development (BPD) Roadway Standards Chief *shall* approve the reduced-conflict intersection as the preferred traffic control alternative.

3.2 ICE Process

The ICE process is conducted in two distinct phases. The first phase, Scoping, is usually done early in the project development process prior to life cycle 11. The purpose of the scoping phase is to prepare a memorandum that recommends traffic control alternatives for further evaluation in the Alternative Selection ICE worksheet. The second phase, Alternative Selection, involves a more detailed evaluation of the alternatives and is documented in the ICE worksheet to assist the Region in selecting a traffic control, lane configuration and intersection type for the studied intersection.

The Region shall prepare the scoping memorandum during the planning phase (refer to FDM 11-25-3.2.1) and approve or prepare the Alternative Selection ICE worksheet (refer to FDM 11-25-3.2.2).The region shall submit the scoping memorandum to BTO for review prior to Region supervisor approval. Also, include the scoping memorandum as an attachment to the ICE worksheet. All approvals shall occur once public input is taken into consideration, as close to the 30 percent design as possible. BTO will provide comments to the region within 20 working days.

3.2.1 Scoping

As part of the scoping process, the Region shall summarize the findings of the analysis in a memorandum that should include the following sections (described below):

- Crash Diagrams
- Signal & Multi-Way Stop Warrants
- Operational Analysis
- Feasibility of Alternatives
- Conclusion and Recommended Alternatives for future consideration

Crash Diagrams

It is important to provide crash diagrams rather than just aggregate crashes because individual crash types and their approximate location must be known in order to choose the appropriate safety countermeasures. Crash records for the most recent five years available should be obtained from the Wisconsin Traffic Operations and Safety Laboratory, WisTransPortal Project site (http://transportal.cee.wisc.edu/services/crash-data/).

Signal & All-Way Stop Warrants

All-way stop control warrants are discussed in the Traffic Guidelines Manual within section 13-26-5 found at (https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/tgm/index.shtm) and signal control warrants are discussed in the MUTCD Section 4C and the TSDM Chapter 2 (https://trust.dot.state.wi.us/extntgtwy/dtid_bho/extranet/manuals/tsdm/ch02.shtm). All warrants shall be evaluated for traffic volume data collected on a typical weekday (i.e. Tuesday through Thursday) for most locations. Installation of a traffic signal can be considered when warranted within 5 years of construction. MUTCD - 4B.03 discusses advantages and disadvantages of Traffic Control Signals; MUTCD - 4B.04. discusses Alternatives to Traffic Control Signals.

Operational Analysis

A capacity analysis must be performed for existing traffic control with forecasted traffic volumes for the design year. The capacity analysis shall be performed using the 2010 Highway Capacity Manual (HCM) Methodology (e.g. Highway Capacity Software, Synchro). Consult with the central office or regional forecasting team for design year traffic projections. Evaluate the existing and expected pedestrian and bicycle traffic. Discuss the need for pedestrian and bicycle facilities at the intersection.

Feasibility of Alternatives

Briefly discuss the potential environmental impacts, right-of-way impacts, safety implication, site deficiencies, the major expected costs for each alternative, coordination with local government that may be required and any other important consideration that may be unique to the project or location. Consider all of these when establishing a budget during the scoping process. To ensure all alternatives are viable based on the established project budget the expected higher cost alternative shall be used for budgeting purposes.

Conclusions

Briefly discuss the viable alternatives recommended for further consideration in the Alternative Selection portions of the ICE Worksheet (Attachment 3.1). Document the findings in the project file and share the data and memorandum with WisDOT's project development team.

The required data necessary to perform the analysis recommended for the scoping memorandum as described herein may not be available or the Region may not be able to collect it in time. In this case the Region shall document in the scoping memorandum the process followed to determine the viable alternatives recommended for further consideration in the Alternative Selection portions of the ICE worksheet taking into consideration the recommended process discussed in this section.

The scoping memorandum will also serve to identify intersections that do not require further evaluation of traffic control alternatives in the Alternative Selection ICE worksheet. For example:

- Intersections identified as requiring minor improvements such as additional turn lanes or stop control on the minor road
- Intersections that don't meet signal warrants for current or design year traffic volumes
- The existing traffic control or intersection type does not present capacity or safety concerns for the current or design year traffic at the studied intersection
- Intersection is part of a signal corridor and an alternative traffic control is expected to disrupt traffic flow.
- The intersection requires railroad preemption as determined by WisDOT Railroad's and Harbors Section (RHS) and BTO

If the region requires further assistance in determining if an intersection requires further evaluation in the Alternative Selection ICE worksheet consult with BTO.

3.2.2 Alternative Selection

Even if an intersection meets warrants for traffic control, that treatment may not be justified. The alternative selection process requires engineering judgment. Whether an intersection justifies a particular type of intersection control, lane configuration or intersection type is based upon a number of factors. The ICE worksheet shall document those factors as a minimum to support a traffic control alternative. A report can be submitted if desired as an attachment to the worksheet format. Refer to appendices to determine the minimum data and exhibit requirements to document the findings.

The worksheet form represented in Table 3.1 shall be used to prepare the ICE report. The form in Word processing macro-enabled template format (DOTM) format is available at Attachment 3.1.

The factors and the required information to document the alternative selection process are shown in Table 3.1 below.

Table 3.1 Intersection Control Evaluation - Alternative Selection

Factor	Description
Safety	Request or develop crash diagrams as indicated for the scoping phase and evaluate for trends. Explain what type and percent of crashes will be reduced by each alternative. (Refer to the Federal Highway Administration (FHWA) safety program website (http://safety.fhwa.dot.gov/tools/crf/resources/#cmfc) For information on Crash Reduction Factors.) Provide an overview of access near the intersection and side road traffic impacts for each alternative.
Operational Analysis	Request or develop the capacity analysis for existing control as described for scoping. Request or develop the warrant analysis as described for scoping. Perform a capacity analysis for the selected alternatives with design year peak hour traffic volumes. Include delay, LOS and volume to capacity ration (v/c) for each movement and overall for each peak hour. Document the 95th percentile queues for each movement and each peak hour. Identify any queue impacts on adjacent intersections and driveways. On routes parallel to a freeway, consider the capacity of the intersection to accommodate 5 percent to 20 percent diverted traffic due to incidents on the freeway. Document railroad crossings within 1000 feet of the intersection and discuss if mitigation measures are needed. Include a preliminary layout for each alternative in the appendix. Accommodate the design vehicle and check vehicles, when applicable, in the design elements. Perform capacity analysis using the Highway Capacity Manual Methodology (HCM 2010). The most current version of approved software's (FDM 11-5-3.7) that support the HCM methodology shall be used.
Right of Way Impacts	List the type of land use and amount of right-of-way acreage impacted. List the number of relocations by land use category, if any. List the access restrictions, if any. Estimate the anticipated right-of-way and real estate costs for each alternative.
Costs	Calculate estimated costs for each alternative. Include right of way costs. Document the cost estimate process by attaching a cost estimate table that includes the main items that account for the estimated cost of each alternative. Document how the right of way acquisition costs were estimated. Consider if there are significant operations and maintenance costs. Use conceptual drawing as the basis for the cost estimate.
Practical Feasibility	List any concerns that the traffic control alternatives may present. Identify major impacts on businesses, parking availability, real estate and utilities. Describe the use of the intersection as part of a diversion route and the implications this may have on the design (e.g. alternative selection, design vehicle, lane configuration).

Factor	Description
Pedestrians and Bicycles	Describe the need for pedestrian and bicycle facilities. Review comprehensive land use plans or other planning documents for the inclusion of facilities. Identify nearby pedestrian generators, bike routes, transit stops and if the intersection is on a Safe Route to School State if and what facilities are proposed, within, or near the project limits. Ensure that the American with Disabilities Act (ADA) rules and regulations are met for pedestrians and bicycle facilities.
OSOW Freight Network	Identify nearby OSOW generators. Evaluate and consider the following if either intersecting road is on the OSOW freight network, is a significant diversion route or near a freight origin or destination: - Vertical and horizontal clearance shall account for the OSOW vehicle path (e.g. path to avoid low clearance of monotubes) - Need for additional paved areas, removable signing or gated connection needed to accommodate the path of the OSOW vehicle. - Geometric features of the intersection to account for the OSOW vehicle path. - Grading for the circulatory roadway of a roundabout for the lower clearance of OSOW vehicles. - Design of a roundabout’s central island (e.g. shape, apron) to account for the path of an OSOW vehicle.
Environmental Impacts	Describe the type (i.e. historical, archeological, wetlands or hazardous material) and amount of environmental acreage affected by each alternative.
Recommendation	Discuss each alternative and make a recommendation as close to the 30 percent design as possible.

3.2.3 Appendices to Attach

The completed worksheet report shall include supporting data, diagrams, and software input/output reports that support the findings of the study. The following is the minimum data required as part of the ICE.

Existing Geometrics

- Document the existing geometrics of the intersection being considered for improvement.
- Provide an exhibit with an aerial view of the intersection that highlights the existing geometrics, traffic control, right of way limits, speed limits, the location of schools or other significant land uses near the intersection and all adjacent driveways.
- Discuss geographic features that may influence the selected alternative (e.g. severe grades, wetlands, parkland).
- Provide a map showing the intersection in relation to parallel roadways and its relationship to other access points along the corridor.

Crash Data

- Obtain crash data for the most recent five years from the WisTransPortal site (http://transportal.cee.wisc.edu/services/crash-data/)).

Traffic Volumes

- Show the most recent 12-hour turning movement counts available.
- Provide future turning movement volumes for the AM and PM peak hours using a WisDOT provided forecast or pre-approved growth rates.
- Provide pedestrian and bicycle volumes by approach, if applicable.

Operational Analysis

- Provide warrant analysis worksheets (electronic copies must be available upon request)
- Provide software inputs/outputs (electronic copies must be available upon request)

Costs & Right of Way Impacts

- Provide itemized tables documenting the major cost items including right of way cost estimates.
- Document how right of way costs were obtained.

Proposed Geometrics & Traffic Control Alternatives

- Include a preliminary layout of the intersection showing the proposed geometrics for each traffic control alternative. Show the relationship of the proposed designs to the existing geometrics and the proposed changes to adjacent driveways.
- Account for the design vehicle and OSOW vehicles in the preliminary intersection layout, if applicable. Include truck turning template exhibits.

LIST OF ATTACHMENTS

Attachment 3.1 Attachment 3.1 Intersection Control Evaluation Worksheet

FDM 11-25-5 Left Turn Lanes *March 4, 2013*

5.1 Introduction

A left-turn lane at intersections where left turns are frequent is always desirable from a safety and capacity standpoint because exclusive left turn lanes are the safest and most effective way to separate left turning traffic from through traffic.[54] A left-turn bay can significantly improve operations and safety at an intersection by effectively separating those vehicles that are slowing or stopping to turn from those vehicles in through traffic lanes. This minimizes turn-related crashes and unnecessary delay to through vehicles. [55]

5.2 Warranting Criteria

Exclusive left-turn lanes are provided in order to enhance the safety and to facilitate the movement of through traffic. The primary factors to consider when determining the need for an exclusive left-turn lane are the left-turn traffic volume, opposing traffic volume, crash history and experience. A capacity analysis is generally used to determine turn lane requirements at signalized urban intersections. Additional factors to consider include:

- Median width,
- Available right of way,
- Roadway geometry (e.g., shifting of adjacent travel lanes),
- Impacts to other roadway features (e.g., bike accommodations, terrace, and sidewalk),
- Construction and right of way costs, and
- Design classes of the intersecting roadways.

As a general policy, provide exclusive left-turn lanes at the following locations (if a left turn or u-turn is permitted at that location):

- All median openings on rural divided highways[56] and on urban transitional and high-speed divided highways[57]
- At median openings on urban low-speed roadways unless left-turn PHV<20 vph or sideroad/driveway AADT<400 vpd[58]
- All intersections on a 2-lane community bypass[59]

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[54] MNDOT Road Design Manual ch. 5 (*19)* Rural Intersections - Turn lanes - Left-Turn Bypass Lanes. In *MNDOT Road Design Manual ch. 5: At-Grade Intersections* Minnesota DOT, 2000, sect. 5-4.01.04, pp.5-4(2). http://www.dot.state.mn.us/design/rdm/english/5e.pdf.

[55] See Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf., pp. 21-22)

[56](*12) Transportation and Land Development*, 2nd edition. Institute of Transportation Engineers, 2006., p.5-47, "Warrants for Left-Turn Bays"

[57] *(20) Minimum Required Turn Lane Storage Lengths & Tapers For Left & Right Turn Lanes At Signalized & Non-signalized Intersections. (DRAFT).* Wisconsin DOT, 2010.

[58] *(20) Minimum Required Turn Lane Storage Lengths & Tapers For Left & Right Turn Lanes At Signalized & Non-signalized Intersections. (DRAFT).* Wisconsin DOT, 2010.

[59] *(21) Review of Wisconsin Bypass Road Design Practices February 13-14, 2006. (Final).* Federal Highway Administration Resource Center, 2006. http://www.dot.wisconsin.gov/library/publications/docs/wis-bypass-report.pdf.:

pp.5-6, "Left Turn Lanes – Part 1:

- Intersections meeting the warrants of Table 5.1
- Signalized intersections
- To replace TWLTLs at non-signalized intersections/driveways where the left turn volume exceeds100 vph[60]

Generally, consider providing an exclusive left-turn lane if the construction year AADT on the main road exceeds 4,000 and the side road AADT exceeds 400. Left turn lanes for OSOW movements on OSOW routes should be provided independent of the AADT guidance, depending on frequency of load.

Left turn lanes in the middle of the highway have a strong proven safety benefit at intersections, whether they are signalized or unsignalized. Left turn lanes should be a standard at all intersections on bypass roads. Left turn lanes are not “bypass lanes” installed to the right of the through lane at an intersection; rather left turn lanes are positioned to the left of the high speed through traffic lane.”
Also, Appendix B, p. i, “Geometric Design – Intersections:
1. Left turn lanes with positive offset on the bypass at all at-grade intersections to enhance left turn safety””
[60] *(22) Rationale for Median Type Recommendations.* Kentucky Transportation Cabinet, 2008. http://www.planning.kytc.ky.gov/congestion/medians/Median%20Type%20Guidelines.pdf.

Table 5.1 Operational Warrants for Left-Turn Lanes at Intersections on Two-Lane Highways [61]

Opposing Volume (veh/hr)	Advancing volume to warrant a left-turn lane (veh/hr) with 5 percent left turns	with 10 percent left turns	with 20 percent left turns	with 30 percent left turns
	40-mph Operating Speed			
800	330	240	180	160
600	410	305	225	200
400	510	380	275	245
200	640	470	350	305
100	720	515	390	340
	50-mph Operating Speed			
800	280	210	165	135
600	350	260	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
	60-mph Operating Speed			
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240

5.3 Design Criteria

See FDM 11-25-2.1 for guidance on Intersection *Design Vehicles* and Intersection *Check Vehicles* (including *OSOW Vehicles)*.

The assumed speed of a vehicle making a minimum radius left turn is 10-15 mph.[62]

Develop Intersection designs, including the location and shape of the median nose and median opening, by using design vehicle turning templates and an appropriate control radius. Design the intersection so that the Design Vehicle(s) for the turning movement(s) stays in lane (see Table 2.1). Larger vehicles may encroach on other lanes as shown in Figure 2.2 and Table 2.1.

Design movements to allow vehicles to turn with a smooth continuous radius. Simultaneous opposing left turns must be able to complete their turns with a clearance between them as they pass each other of 10 feet desirable / 3 feet minimum for opposing single left turn lanes (see FDM 11-25-5.4.3.1 for guidance on multiple left turn lanes). [63]

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[61] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p. 685, Exh. 9-75, “Guide for Left Turning Lanes on Two-Lane Highways”

[62] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., chapter 9, p.690

[63] Desirable Minimum clearance per (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf., sect. 36-3.03, “Left Turn Lane Designs”

Restrict on-street parking near the intersection if needed to aid in truck turning movements.

5.3.1 Widths

The width of a left-turn lane is desirably the same as the width of the through lane. Curb adjacent to the left-turn lane is offset to at least the width of the gutter. Provide a turn-lane width of 12 ft on high-speed and transitional rural and suburban arterial highways. Desirably, fully develop the median width upstream from a left-turn lane taper before introducing the taper (i.e., fully shadow the left -turn lane).

Narrower turn lanes are often necessary on urban arterials because of restricted right-of-way and median widths. The minimum and desirable widths for non-slotted left-turn lanes are shown in Table 5.2 below.

The desired minimum separator width at a signalized intersection is 8 feet face to face; the absolute minimum width is 6 feet face to face. This width is required for signal and sign/structure placement, and pedestrian refuge

Table 5.2 Median, Separator, and Turn Lane Widths for non-slotted Left Turn Lanes on Low-Speed Urban Arterials (Minimum Widths)

		Highly Developed Area	**Outlying Area**	
Left-turn lane Width (to gutter flange line)	Minimum	10 ft		
	Desirable	11-12 ft		
Separator Width (f/c-f/c)* *	Minimum	The greater of 6 feet OR Fixed object width (e.g., sign or signal head) + 2 feet on each side.	The greater of 8 feet OR Fixed object width (e.g., sign or signal head) + 2-feet on each side.	
	Desirable	10 feet or greater but not less than Fixed object width (e.g., sign or signal head) + 2 feet on each side.		
Total Median Width between opposing traffic lanes where cross traffic storage is **NOT** required.		Separator width (f/c – f/c*) + gutter width on each side of separator + left-turn lane width.		
Total Median Width between opposing traffic lanes where cross traffic storage **IS** required.		**<u>Low Speed Urban Roadways</u>** **Desirable**: the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 30 feet. **Minimum**: the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 24 feet. **<u>Transitional and High Speed Urban Roadways</u>** the greater of f/c – f/c* width + gutter width on each side + left-turn lane width, or 30 feet.		

* f/c-f/c width is the face of curb to face of curb distance between the curb adjacent to the left-turn lane and the curb adjacent to the opposing traffic lane.

See FDM 11-20-1 under "Medians" for further guidance on median widths.

5.3.2 Median End Treatment

A typical intersection does not have a continuous physical edge of traveled way delineating the left-turn path. Instead, the beginning and end of the left-turn path are delineated by:

1. The centerline of an undivided crossroad or the median edge of a divided crossroad, and

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(*23) A Policy on Geometric Design of Highways and Streets 2011*, 6th edition. AASHTO, 2011. www.transportation.org., p.9.138

2. The curved median end

Under these circumstances, a simple curve for the minimum assumed edge of left turn - known as the control radius - is satisfactory. The larger the control radius, the better it will accommodate a given design vehicle, but the resulting layout will have a greater length of median opening and greater paved areas than a minimum radius. These may result in erratic maneuvering by small vehicles, which may interfere with other traffic. On the other hand, a smaller control radius will require wider pavement on the receiving leg to accommodate larger vehicles.

The following control radii can be used for minimum practical design of median ends:

- 40 ft accommodates P vehicles and occasional SU vehicles with some swinging wide;
- 50 ft accommodates SU-30 vehicles and occasional SU-40 and WB-40 vehicles with some swinging wide;
- 60-ft is usually appropriate for right-angle urban intersections (see Attachments 5.1 and 5.2);
- 75 ft accommodates SU-40, WB-40 and and WB-62 vehicles with minor swinging wide at the end of the turn.
- 80 ft is the minimum for rural high-speed 4-lane divided highways (see Attachment 5.4)
- 130 ft accommodates WB-62 vehicles and occasional WB-65 vehicles with minor swinging wide at the end of a turn.[64]

For a median width of 10 ft or more, the bullet nose is superior to the semicircular end and is the preferred design. A bullet nose is designed to closely fit the path of a turning vehicle and results in less intersection pavement and a shorter median opening than the semicircular shape. The bullet nose is formed by two symmetrical portions of control radius arcs (see R3 - R6 in Attachment 5.1 - 5.3). These arcs need to be large enough to accommodate the turning path of the design vehicle. Assume that the inner wheel of each design vehicle clears the median edge and centerline of the crossroad by 2 ft at the beginning and end of the turn without encroachment on adjacent lanes.

On the OSOW Freight Network, use the vehicle inventory of OSOW check vehicles, Attachment 2.1 that may require alternative intersection geometrics The OSOW Freight Network map is available at the following link, http://dotnet/dtid_bho/extranet/maps/docs/freightnetwork.pdf Alternative nose configurations may be warranted that allow passage of OSOW vehicles while providing direction to turning vehicles.

Median refuge increases safety for pedestrians and bicyclists crossing a street. A median cut-through is the recommended design for accommodating pedestrians/bicyclists - especially at unsignalized intersection. The face-face median width for pedestrian/bicyclist refuge is desirably 8-feet or greater and minimally 6-feet. See FDM 11-46 for additional guidance on pedestrian accommodations and crossings.

5.3.3 Length

See FDM 11-25-2.3 for guidance on calculating the length of a left turn bay. The length of a median left-turn lane must be adequate for storage or speed change of left-turning vehicles and the entering taper.

Coordinate with the region traffic engineer's staff in determining the required storage length at signalized intersections. Consider using traffic control devices with left-turn indicators when the number of left-turning vehicles exceeds 100 per hour. For additional information, see pp 713-723 of the 2004 GDHS[65] and the Highway Capacity Manual [66]

Attachment 5.1 and Attachment 5.2 provide guidance on the length and design of turn lanes for urban highways and streets.

Attachment 5.4 illustrates a left-turn lane on a typical rural expressway and includes a table that relates the length of a left-turn lane to the type of rural at-grade intersection into which the traffic is turning.

5.4 Special Designs

5.4.1 Slotted Left-Turn Lanes

A problem with left-turn lanes is the inability of drivers in opposing left-turn bays to see past each other to detect oncoming traffic and pick an adequate gap to complete their maneuver. Although it is desirable to provide a

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[64] (*23) A Policy on Geometric Design of Highways and Streets 2011*, 6th edition. AASHTO, 2011. www.transportation.org., section 9.8.2

[65] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[66] (*24) Highway Capacity Manual 2010*, 5th edition. Transportation Research Board of the National Academies, 2010.

positive offset, as shown in Attachment 5.3 this may not be possible at all locations. Desirably, keep the turning lane as far to the left as practical on wider medians, thus creating a slotted or channelized left-turn lane, as shown in Figure 5.1.

One possible consequence of poor alignments is that protected left turn arrows will need to be prematurely added for low volume left turn movements because of crashes resulting from the poor visibility. This will increase the delay at the intersection.

The total width of a left-turn island is defined as the distance between the right edge of the turn lane and the median edge of the travel lane.

If the f/c – f/c width of a left-turn island would be less than 4 feet, then install a flush left-turn island of contrasting pavement or color to delineate the turning lane from the through lane. Otherwise, install a raised left-turn island and make the lateral offset between the curb face of the left-turn island and the adjacent through lane equal to the offset from the curb face of the median to the same adjacent through lane. See Figure 5.1.

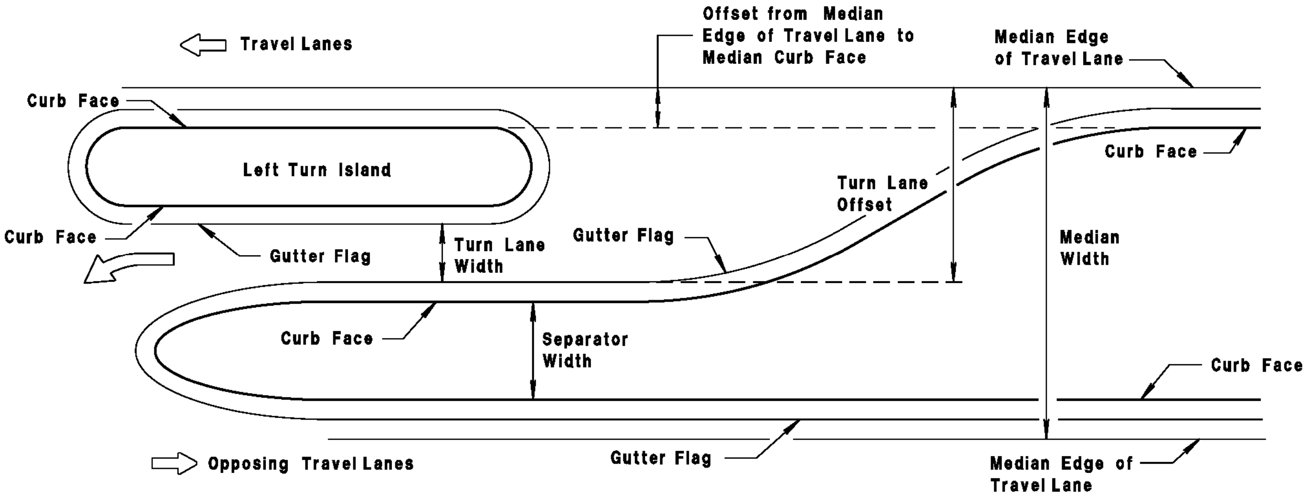

***Figure 5.1** Urban Slotted Left Turn Lane with Left-Turn Island*

The width of the channelized turn lane is 14-feet desirable / 12-feet minimum between the gutter flag of the left turn island and the gutter flag of median separating the left turn lane from the opposing travel lanes (see Figure 5.1). The desirable f/c/ - f/c width is18-feet (using a 14-ft lane and 2-foot gutter on both sides), which provides some potential for passing a stalled vehicle[67]. The minimum f/c/ - f/c width is 16-feet - except, 14-feet may considered under the following conditions:

- Sloping face curb is used (if appropriate) on both sides, or
- Trucks are prohibited on the cross street, or
- Current and projected Traffic counts show a small number of SU-trucks (less than 10/week total) and WB-trucks (less than 0.5/week total) making the turn

However, if the intersection is on the OSOW Freight Network, this width may need to be increased to accommodate OSOW vehicle turning movements.

An offset and slotted left-turn design is illustrated on Attachment 5.3. For additional guidance, see pp 723-724 of the GDHS68.

5.4.2 Two-Way Left-Turn Lane (TWLTL)

Two-way left-turn lanes (TWLTLs) consist of a traffic lane in the median area, 14-16 feet in clear width, delineated by pavement marking strips. The lane serves as a *separation for opposing lanes of travel,* an *acceleration lane* for vehicles turning left to enter the street from midblock driveways, and can be utilized as a *detour route* for maintenance work in adjacent lanes. It also allows easier and safer emergency vehicle movement, particularly during peak-hour periods.

[67] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004. "Design Widths of Pavements for Turning Roadways" - Case IIA (tangent) can be interpreted as 18-ft between two vertical-face curbs.
[68] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

TWLTLs are intended for use by vehicles traveling in either direction for *deceleration* and *refuge* while making a *midblock left-turn* maneuver. Use of two-way left-turn lanes for passing maneuvers is prohibited and must be signed appropriately.

In general, only use TWLTLs in an urban setting where operating speeds are relatively low and where there are no more than two through lanes in each direction. Consider installing a two-way left-turn lane (TWLTL) in existing commercial or residential areas where the existing roadway is undivided (flush median) and where there is a combination of traffic congestion and numerous left-turn maneuvers, coupled with rear-end accidents. Provide median refuge at intersections, particularly unsignalized intersections, for pedestrian crossing. Urban or suburban arterials and collectors are common candidates for a TWLTL. A TWLTL mid-block treatment is less desirable on major arterials and arterials with access management priorities.

Use the following design criteria for TWLTLs[69]:

- Posted speed: Only use on roads with posted speeds <=45 mph
- TWLTL widths: 14.0-ft Desirable; 12.0-ft Minimum; 16.0-ft Maximum
- Design year AADT:
    - 3-Lane TWLTL: between 8,000 and 17,500 vpd
    - 5-Lane TWLTL: 24,000 vpd maximum
    - 7-Lane TWLTL: **NOT ALLOWED**
- Length of TWLTL: The length of the TWLTL should have sufficient length to operate properly at the posted speed. Site conditions and the types of intersection treatments will also influence the length of the TWLTL. Use the following guidelines:
    - Posted speed of 30 mph or less: 500-feet minimum uninterrupted length
    - Posted speed of greater than 30 mph: 1000-feet minimum uninterrupted length
- Railroad Crossings: Do not extend a TWLTL across a highway/railroad grade crossing. Terminate the TWLTL 150 ft to 200 ft in advance of the crossing and provide a raised-curb median adjacent to the railroad. Coordinate with the Region railroad coordinator.
- Intersection Treatment:
    - At signalized intersections and at non-signalized intersections/driveways with left-turning turning volumes > 100vph, convert a TWLTL to an exclusive left-turn lane (see FDM 11-25-2.3 for guidance on turn bay length). Use a raised median at intersections and driveways with a high concentration of left turning vehicles and at other locations as needed for pedestrian and bicycle refuge.
    - If turning volumes to a non-signalized minor street/driveway are low, it is not necessary to convert the TWLTL to an exclusive left-turn lane. However, pedestrians and bicyclists may still need median refuge.
- Operational/Safety Factors: For traffic to move safely through intersections, drivers need to be able to see stop signs, traffic signals, and oncoming traffic in time to react accordingly. Do not locate a TWLTL where there is substandard stopping sight distance. Provide decision sight distance, where practical, in advance of stop signs, traffic signals, and roundabouts. Appropriate design speed intersection sight distance shall be provided for the drivers of vehicles that are stopped, waiting to cross or enter a through roadway.
- Marking and Signing: Mark and sign TWLTLs in accordance with the Manual on Uniform Traffic Control Devices to identify the lane and regulate its proper use. Additional delineation is possible by either using a different type of pavement material with contrasting color or texture, or a mountable raised median. See SDD 15C10, "Raised Pavement Markers" and MUTCD Figure 3-5 for typical details of marking for two-way left-turn channelization. Two-way left-turn lanes are also discussed in the GDHS[70] on pp 474-478

5.4.2.1 Conversion from 4-Lane Undivided to 3-lane TWLTL ("Road Diet")

Consider converting a four-lane facility to a 3-lane TWLTL - commonly referred to as a "Road Diet" - if the following conditions exist:

- High accident rates involving left turning movements, sideswipes, rear-ends, or crossing traffic
- The need for traffic calming (Lowering the average through traffic speeds and reducing weaving)
- Pedestrian and bicyclist safety issues

[69] *(25) Two Way Left Turn Lane (TWLTL).* Wisconsin DOT, 2007.
[70] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

- The existing four-lane facility actually operates similar to a 3-lane facility. The inside lanes operate as the left turn lane and the outside lanes operate as the through lane.
- Projected traffic volumes do not show a drastic increase

Converting a four-lane undivided section to a three-lane cross section may result in less right of way impacts, less environmental impacts and less costs than converting to a wider TWLTL or raised median cross section. The conversion from four to three lanes may also allow the use of wider or designated bike lanes.

Roadways with stop and go traffic such as school buses and delivery trucks or where slow moving heavy vehicles such as long trucks and farm machinery will result in increased through traffic delays. An increased delay for access from side roads may also result with the conversion to three-lanes. A design year ADT of 15,000 - 17,500[71] is typically the maximum capacity for a three-lane TWLTL cross section, but check for adequate Level of Service (LOS) (see FDM 11-5-3).

5.4.3 Multiple Left Turn Lanes

Use multiple left-turn lanes at signalized intersections where traffic volumes exceed the capacity of a single left-turn lane. Fully protected signal phasing is required for multiple left turns (refer to TSDM 3-4-1 for guidance on left turn phasing). Multiple left turn lanes increase capacity for left turning movements and usually improve overall intersection delay and level of service by allowing a shorter cycle length and reallocation of green time to other movements. However, multiple left turns add to the complexity of the driving task. In addition, because multiple left turns increase exposure for cyclists and pedestrians, adequate clearance times for bicycles and pedestrians is critical.

Multiple left turn lanes are usually NOT appropriate where[72].

- A high number of vehicle-pedestrian conflicts may occur.
- Left-turning vehicles do not queue evenly among the left turn lanes because of downstream conditions (e.g., a high potential for downstream weaving may exist).
- Channelization markings within the intersection may become obscured or confusing
- There is insufficient right-of-way to provide adequate turning maneuver space for the design vehicle

5.4.3.1 Design Considerations for Multiple Left Turn lanes

Consider dual left turn lanes at any signalized intersection where left turn demand exceeds 300 vehicles per hour or if the storage length exceeds 300 feet; consider triple left turns where left turn demand exceed 600 vehicles per hour[73]: Determine the actual need by performing a signalized intersection capacity analysis.

Turn lane widths for multiple turn lanes are 12-ft desirable and 11-ft minimum.

Provide adequate throat width on the intersection leg receiving the multiple left turns to compensate for turning vehicles offtracking and for the relative difficulty of side-by-side left turns. On the other hand, avoid excessive pavement width, because this can mislead drivers. An Intersection where the turning angle is greater than 90-degrees may require a wider throat width than an Intersection where the turning angle is 90-degerees or less[74].

Provide a separation between vehicles turning side-by-side of 4-feet desirable / 3-feet minimum (see Figure 5.3). Provide a clearance between simultaneous opposing left- turns as they pass each other of 10 feet desirable / 3-feet minimum. It may be necessary to offset opposing approaches to avoid conflicts in turning paths. If opposing left-turns have inadequate clearance between them then provide separate protective signal

[71] (*26)* Geometric Design of Lanes - Continuous Two-Way Left-Turn Lanes (TWLTLs). In *IADOT Design Manual ch. 6: Geometric Design* Iowa DOT, 2001, sect. 6C-6, pp.1-4. http://www.iowadot.gov/design/dmanual/06c-06.pdf.,(*27)* Facility Selection / Two - Way Left - Turn Lanes. In *MODOT Engineering Policy Guide ch. 200: Geometrics* Missouri DOT, 2012, sect. 232.3. http://epg.modot.org/index.php?title=232.3_Two_-_Way_Left_-_Turn_Lanes.

[72] *(28)* Criteria for the Geometric Design of Triple Left-Turn Lanes. *ITE Journal*, vol. 64, no. 12, 1994, pp.27-33. http://turnlanes.net/files/criteria_for_the_geometric_design_of_triple_left-turn_lanes.pdf.,(*29)* Individual Movement Treatments / Multiple Left-Turn Lanes. In *FHWA-HRT-04-091: Signalized Intersections: Informational Guide* Federal Highway Administration Turner-Fairbank Research Center, 2004, ch. 12.1.2, pp.318-319. http://www.tfhrc.gov/safety/pubs/04091/04091.pdf.
(30) Triple Left Turn Lanes At Signalized Intersections. BC131 *(FINAL).* Florida DOT, 2002. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BC131rpt.pdf.

[73] Same references as in previous footnote

[74] (*31) NYSDOT Highway Design Manual ch. 5*: *Basic Design*. New York State DOT, 2011. https://www.dot.ny.gov/divisions/engineering/design/dqab/hdm/hdm-repository/chapt_5_final.pdf., sec. 5.9.8.2 B, p.5-125

phases.

Use lane line extensions to delineate the turning path through an intersection in order to reduce the potential for sideswipe collisions and to increase the efficiency of left-turn operations. This is particularly important where less than desirable clearances are used. Determine lane line (or guideline) and width requirements by plotting the swept paths of the selected design vehicles. There should be no conditions that obscure, or result in, confusing pavement markings within the intersection.

Check all turning paths of multiple left turn lanes with truck turning templates allowing 2-ft.between the tire path and edge of each lane.

Provide adequate signing and marking to make the intended operation clear to every road user. Each turn lane should be marked with turn arrows and "ONLY" legends as appropriate.

Provide a raised median island on the receiving leg of the intersection to provide drivers on the inside lane with a visual point of reference to guide the vehicle through the left-turn maneuver.

Because of the added width, signal-timing intervals for bicycle and pedestrian movements require special attention,

5.4.3.1.1 Dual Left Turn Lanes

For details on dual left turn lanes, see Figure 5.4 and Table 5.3.

The receiving roadway needs to carry two through lanes a sufficient distance to allow the effective utilization of both lanes (As a minimum, use the desirable values from the "Tangent Prior to Merge" column in Table A.2.2, from Attachment 2.2).

Assume that the Design Vehicle from Table 2.1 will turn from the outside lane of the dual left turn lanes. Desirably, the inside vehicle should be a SU but, as a minimum, the other vehicle can be a passenger car, [75] if any or all of the following conditions are present:

- Right-of-way is limited
- Trucks are prohibited on cross streets
- Cross street volume is minimal (< 400 ADT) and route is unlikely to be used as a detour route for a nearby higher volume roadway

Table 5.3 shows throat width guidelines for dual lane left turn lanes where the left turning vehicles have a turning angle of 90-degerees or less.

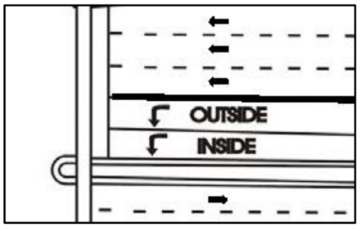

Figure 5.2 Outside and Inside Lanes for Dual Left Turn Lanes

[75] ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-3.05(b), "Dual Turn Lanes / Design"

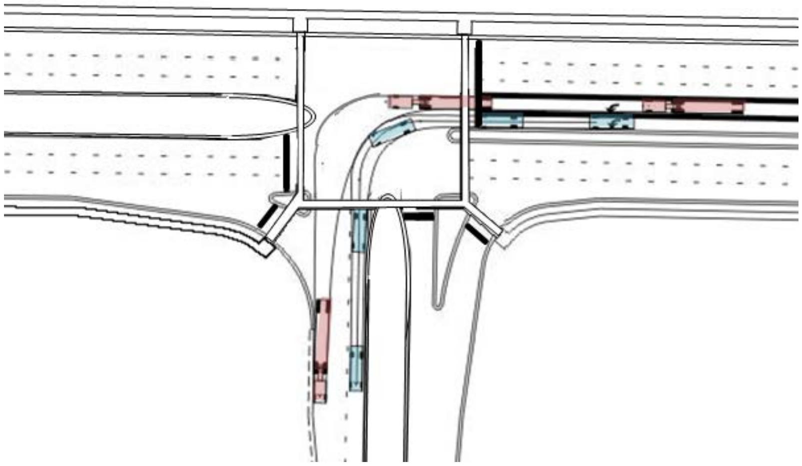

Figure 5.3 ***Dual Left Turn Lane with Throat Widening on Departure Leg - Design Vehicle & Single Unit Vehicle Turning Together***

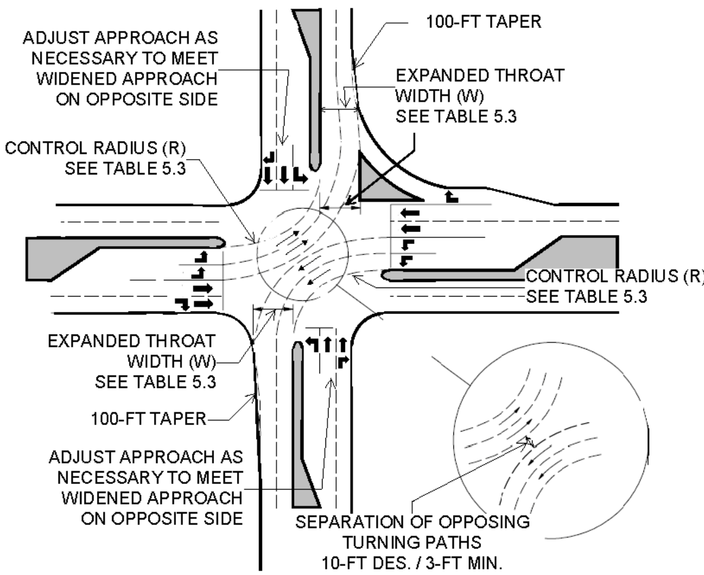

Figure 5.4 ***Dual Left Turn Lanes***[76]

[76] Adapted from (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. , Figure 36-3U.

Table 5.3 Expanded Throat Width (W) Guidelines for Dual Left Turn Lanes[77]

Control Radius (R) (feet)	Intersection Design Vehicle =	Expanded Throat Width (W) (feet)	
		'SU' truck or Passenger Car	'WB' truck
75		33 + gutter width(s)	38 + gutter width(s)
100		31 + gutter width(s)	35 + gutter width(s)
150		30 + gutter width(s)	33 + gutter width(s)
200		30 + gutter width(s)	30 + gutter width(s)

5.4.3.1.2 Triple Left Turn Lanes

Consider triple left turn lanes only if meeting the following conditions[78]:

- An operational analysis of the intersection shows that a triple left turn lane would correct a situation in which the overall capacity of the intersection is seriously deficient, and that no other geometric or signal modifications would correct the deficiency. Take into account the effects of adjacent intersections, including:
    - Traffic backup from a downstream signal on the receiving roadway
    - Relative turning movement distribution at a downstream intersection that would compromise the ability of the receiving lanes to store the left turning vehicles
    - The receiving roadway also accommodates heavy volumes from other approaches.
    - Upstream features that would make it difficult to distribute approaching left turning vehicles over the three left turn lanes (e.g. a heavy single lane exit ramp from a freeway).
- Triple left turn lanes would not cause a safety problem or aggravate an existing safety problem - including bicycle and pedestrian safety.
- The signal-timing plan must be able to provide adequate pedestrian clearance intervals for all phases.

Typically, design triple left turn lanes using the Design Vehicle from Table 2.1 in both the outside and middle lanes, and an SU vehicle in the inside lane. Desirably, design triple left turn lanes using a WB-65 vehicle (WB-67 if near a freeway) in both the outside and middle lanes, and an SU vehicle in the inside lane. As a minimum, design triple lane turns using an SU vehicle and two P vehicles turning simultaneously with a minimum 4 feet separation between the swept paths of the vehicles. The SU vehicle should be able to turn in all lanes.

Triple left turn configurations featuring three exclusive left turn bays (Type A) are preferable to either two exclusive left turn bays plus an exclusive left turn trap lane (Type B), or two exclusive left turn bays plus an optional through-left lane (Type C)[79].

Although three continuous downstream receiving lanes are desirable in order to avoid a lane drop, the receiving roadway needs to carry three through lanes a sufficient distance to allow the effective utilization of those lanes - and at least two continuous downstream lanes exist beyond that point. As a minimum, use the desirable values from the "Tangent Prior to Merge" column in Table A.2.2, from FDM 11-25-2, Attachment 2.2.

[77] Adapted from (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf., Figure 36-3T,and (*32) OHDOT Location & Design Manual, Vol.1, Roadway Design ch.400*: *Intersection Design*. Ohio DOT, 2006. http://www.dot.state.oh.us/roadwayengineering/standards/Publications/LDM/2006-07-21/400_jul06.pdf., Figure 401-11E

[78] *(30) Triple Left Turn Lanes At Signalized Intersections.* BC131 *(FINAL).* Florida DOT, 2002. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BC131rpt.pdf., p6-7 to 6-9 / 132-134pdf

(33) Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report. FHWA/TX-11/0-6112-1. Texas Transportation Institute, Texas A&M University, 2011. http://tti.tamu.edu/documents/0-6112-1.pdf., pp.6-5 to 6-9 / 121-125pdf

[79] *(28)* Criteria for the Geometric Design of Triple Left-Turn Lanes. *ITE Journal*, vol. 64, no. 12, 1994, pp.27-33. http://turnlanes.net/files/criteria_for_the_geometric_design_of_triple_left-turn_lanes.pdf.

5.4.4 Shared left-turn/thru lanes at Signalized Intersections

Shared left-turn/thru lanes are not desirable at signalized intersections. Only use shared left-turn/thru lanes on minor low-speed streets or on intersection legs where it is physically impossible to provide separate lanes. If used, monitor their crash history, especially along principal roads.

5.5 Tee Intersection Bypass Lane

A Tee intersection bypass lane (also known as a "SHOULDER BYPASS AT THREE-WAY (T) INTERSECTION" and as "LEFT TURN BYPASS LANE") allows a through vehicle to bypass a left-turning vehicle that is stopped in the traffic lane. See SDD 9A1a for a detail.

A Tee intersection bypass lane is not as safe as an exclusive left-turn lanes because left turning motorists need to stop or slow down in the thru travel lane. This makes them vulnerable to rear end collisions by inattentive following motorists. However, a Tee intersection bypass lane is preferable to no left-turn treatment at all and can improve the efficiency of traffic operations.

Use a Tee intersection bypass lane at the following locations on **non-community bypass** 2-lane roads:

- Type A intersections if a left-turn lane is not warranted, or if the construction of a warranted left-turn lane is not technically feasible, leaving no left-turn treatment as the only other alternative,
- Non-Type A intersections if the construction of a warranted left-turn lane is not technically feasible, leaving no left-turn treatment as the only other alternative,
- Consider at non-Type A intersections where a left-turn lane is not warranted.

Do not use a Tee intersection bypass lane at a four-legged intersection.

Use exclusive left turn lanes with positive offsets at all intersections on a 2-lane community bypass. Do not use Tee intersection bypass lanes.[80]

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LIST OF ATTACHMENTS

Attachment 5.1	Urban Median Opening and Intersection Guidelines
Attachment 5.2	Median Openings and Left Turn Lanes in Urban Roadways
Attachment 5.3	Details for Slotted Left Turn Lanes and Median Opening Openings at Urban Intersections
Attachment 5.4	Median Opening with Left Turn Lane on Rural High-Speed 4-Lane Divided Highway

FDM 11-25-10 Right-Turn Lanes *March 4, 2013*

10.1 Introduction

These guidelines apply to right-turn lanes at intersections without channelizing islands. See FDM 11-25-15 for guidance about channelized right-turn lanes.

A right-turn bay can significantly improve operations and safety at the intersection because it effectively separates those vehicles that are slowing or stopping to turn from those vehicles in the through traffic lanes. This separation minimizes turn-related collisions (e.g., angle, rear-end, and same-direction-sideswipe) and unnecessary delay to through vehicles.[81]

The selection of a right turn radius requires consideration of design speed, types of turning vehicles, type of intersection by location (rural, urban or suburban), pedestrian needs and whether the through highway is divided or undivided.

The assumed speed of a vehicle making a right turn at an intersection designed for minimum-radius turns is less than 10 mph.[82]

When providing a designated right turn lane, continue the bicycle accommodation adjacent to the turn lane and thru the intersection (as shown in SDD 15C29). This is particularly important at signalized intersection and intersections with pork chop islands. See FDM 11-46-15 for additional guidance. The Intersection Design Vehicle (see FDM 11-25-2.1 and Table 2.1) does not encroach into a contiguous bike lane between a right-turn lane and a travel lane. Check the swept path of the Intersection Check Vehicle(s) (e.g., a WB-65) to see if it is possible to avoid encroaching into the bike lane without significantly disrupting traffic or going outside of the roadway. Otherwise, consider:

- accepting infrequent bike lane encroachments but consider a warning sign that right turning large trucks pull left before turning.
- If bike lane encroachment is frequent enough to be potentially dangerous, consider:
    - parking restrictions and/or a larger curb radius
    - mark as a shared bike/right-turn lane instead of a separate bike lane and right-turn lane
    - re-design to reduce or eliminate the conflict

10.2 Intersections in Rural and Developing Areas

Refer to Attachment 1.1 for guidance about right turn lanes on rural high-speed highways.

10.2.1 Storage Length

The right turn lane lengths in the standard rural intersection designs (discussed in Attachemnt 1.1) are for deceleration of turning vehicles. Where cross road traffic volumes are high, additional length may be needed to accommodate vehicle storage. Storage requirements should also be evaluated where signals are added to the intersection. See FDM 11-25-2.2 for guidance on queue storage requirements.

The length of turn lane required for vehicle storage should be determined in cooperation with the region traffic engineer's staff based on a length of 25 feet per vehicle stored. If the intersection is on the OSOW Freight Network, depending on frequency of load, it may be appropriate to consider additional length for OSOW vehicles.

10.3 Two-Way Stop-Controlled Intersections on Urban Low Speed and Transitional Roads

Check with traffic operations on the need for right turn lanes. Accommodate transit, pedestrian and bicyclists roadway users.

Use the charts in Figure 10.1 as an aid in determining whether to add a right-turn bay on the major road at a two-way stop-controlled intersection.

See FDM 11-25-10.4 below for guidance on signalized intersections.

[81] See Bonneson & Fontaine in NCHRP Report 457 (*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf., pp. 22-23)
[82] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., p.583, “Minimum edge of Traveled Way Designs”

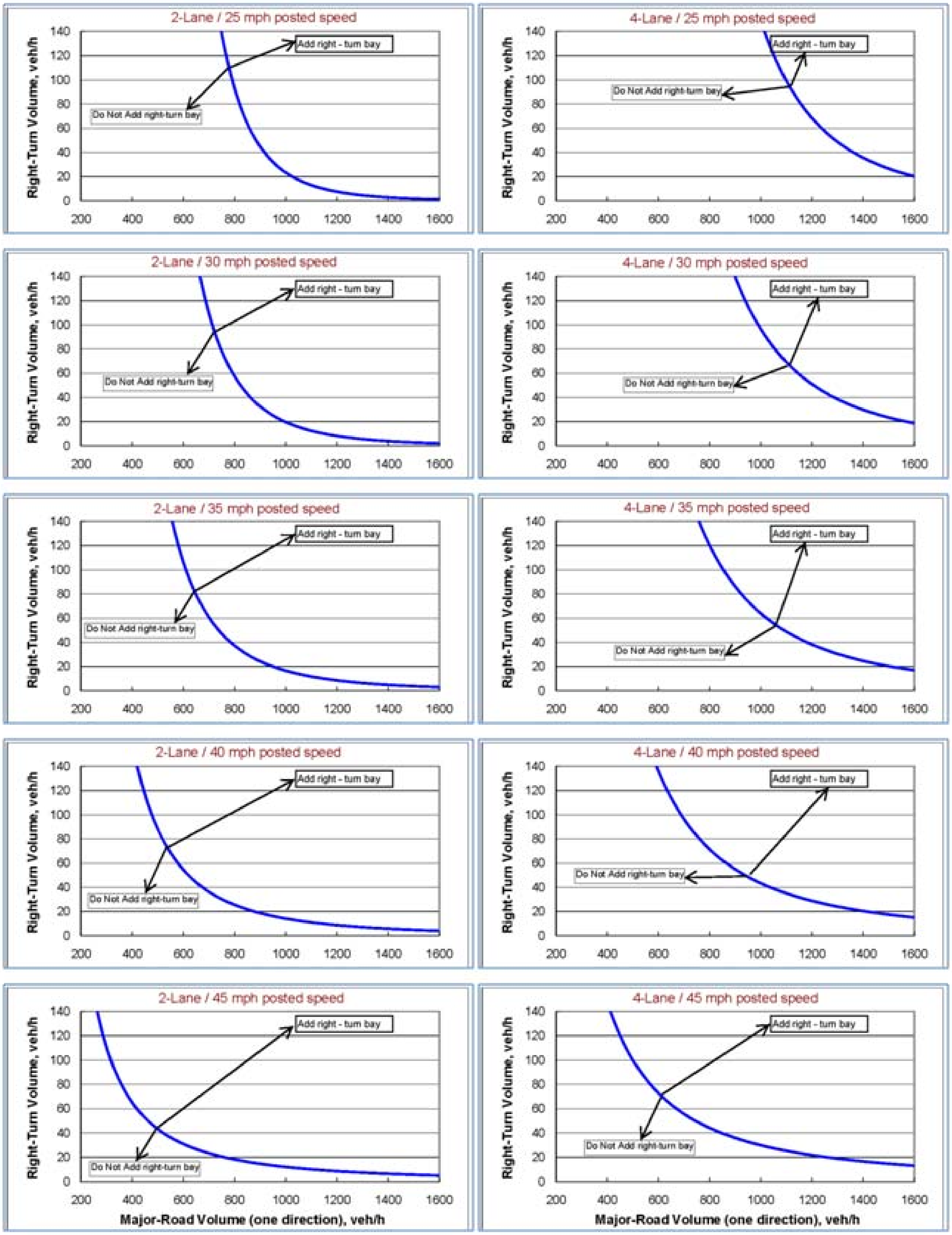

***Figure 10.1* Guidelines for a Major-road Right-turn Bay at Urban Two-way Stop-controlled Intersections**[83]

[83](*13) NCHRP Report 457*: *Engineering Study Guide for Evaluating Intersection Improvements*. TRB, National Research Council, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf., Figure 2.6, p.23 - see also

10.3.1 Corner Curb Radius

Central Business District (CBD) streets are typically undivided and often operate as one-way roadways. A minimum corner radius of 10 feet may be adequate for these streets especially where there is pedestrian activity and little truck traffic. Progressively larger corner radii are required depending on the functional classification of the intersecting street; at least 15 feet for locals, 20 feet for collectors and 25 feet for arterials. Large trucks can be accommodated with these radii if encroachment into the opposing traffic lane can be allowed and parking can be held back from the corner by at least two spaces. See Chapter 9 of 2004 AASHTO GDHS sections, "Effect of Curb Radii on Pedestrians" and "Corner Radii into Local Urban Streets".[84]

Where there are a significant number of trucks turning and encroachment into the opposing lanes cannot be allowed, the corner should be designed using an appropriate turning template or three centered compound curves. See 2004 AASHTO GDHS Exhibit 9-42, "Typical Designs for Turning Roadways". Pedestrian, bicycle and transit accommodations and signal locations need to be included in the design accordingly .

Where truck volumes are not significant, the right turn radius can be as small as 10 feet in downtown streets and 25 feet at intersections with arterial streets. Intersections that handle large numbers of turning trucks require a minimum corner radius of 30 feet to turn onto a four lane divided highway where the semitrailer can encroach into the median lane. Truck drivers will use the median lane when necessary which is allowed under state law for large trucks. A larger radius should be provided where possible. However, a radius greater than 45 feet should not be used because it can cause substantial problems with the location of stop signs, traffic signals, pedestrian push buttons, and crosswalk locations. A large radius also causes crosswalks to be extra long which results in more pedestrian exposure and visibility problems.

The corner radius can be shorter where the intersection is on a street where parking is permitted. However, future growth in traffic volumes may demand that the parking lane be converted to a traffic lane. If this is foreseeable, a large radius should be provided.

For additional guidance, see 2004 AASHTO GDHS sections, "Minimum Edge of Traveled Way Design" and "Design For Specific Conditions (Right Angle Turns"[85].

10.3.2 Lane Width

The width of a non-channelized right turn lane should generally be the same as the width of the through lane. For guidance on the use of narrower lanes, see Table 5.2. The desirable width for channelized right turn lanes is discussed in FDM 11-25-15.

10.3.3 Lane Length

See FDM 11-25-2.3.

10.4 Signalized Intersection Considerations

Consider providing exclusive right turn lanes for all approaches at a signalized intersection. A right turn lane provides refuge for safe deceleration outside a high speed through lane and provides storage for right-turning vehicles to assist in optimizing traffic signal phasing.

Improperly designed right turn radii most likely will result in traffic signal knockdowns. A flat corner curb radius (i.e.,>70 feet) creates a traffic signal design problem when locating the near right traffic signal. The preferred solution is to design a small pork chop island (minimum of 150 square feet) to place the traffic signal and lighting bases, pull boxes, pedestrian pushbuttons, and pedestrian walkways. The island also facilitates channelization of the right turn movement (see FDM 11-25-15 for guidance on channelized right turns).

10.4.1 Dual Right Turn Lanes

Dual right-turn lanes have typically been installed at signalized intersections and at roundabout right-turn bypass lanes on urban arterial roadways and interchange ramps. Determine the actual need by performing a signalized intersection capacity analysis. Use dual right-turn lanes only if necessary because they are particularly difficult for bicyclists and pedestrians[86]. Dual right-turn lanes at signalized intersections are required to be signal-controlled. See FDM 11-26 for guidance on dual right-turn lanes at roundabout right-turn bypasses.

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interactive spreadsheet included in on-line version, "http://onlinepubs.trb.org/onlinepubs/nchrp/esg/figure 2-6.xls" (NCHRP references from "NCHRP Report 457" are reproduced with permission of the TRB through the National Academy of Sciences (NAS))

[84] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.614-621

[85] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.634-639

[86] *(33) Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report.* FHWA/TX-11/0-6112-1. Texas Transportation Institute, Texas A&M University, 2011. http://tti.tamu.edu/documents/0-6112-1.pdf., p.6-2

There are generally two reasons for using dual right-turn lanes[87]:

1. To accommodate high right turn volumes and provide enhanced capacity at intersections where a single right-turn lane is not adequate and a free-flow right turn lane is not advisable
2. To mitigate weaving traffic conflicts, e.g. drivers who are making a left-turn at the next downstream intersection would make their turn from the left-hand lane of the dual right-turn lanes

Research has shown that a well-designed dual right-turn lane does not cause significantly higher crash frequency or severity compared to a single right-turn lane[88] and will usually improve the operations of intersections. The additional deceleration and storage space helps prevent spillover into adjacent through lanes. Right-turning traffic requires less green time, and this time thus can be allocated to other movements. However, because of the added width, signal-timing intervals for bicycle and pedestrian movements require special attention,

Consider using dual right-turn lanes at an intersection with a single right-turn lane - and where the receiving leg has at least two lanes - if one of the following conditions exists[89]:

- The right-turn volume is greater than 500 vph;
- There is not sufficient space to provide the necessary length of a single turn lane because of restrictive site conditions (e.g., closely spaced intersections),
- The required length of a single turn lane becomes excessive (usually about 300-ft or greater)
- The volume to capacity ratio for a single right-turn lane is greater than or equal to 0.90, or LOS is worse than D
- Right-turn green time and green time from an overlap are not sufficient to handle the right-turn volume

There are two (2) types of dual right-turn lane configurations:

1. Shared dual right-turn lanes: the right hand lane (i.e., the curb lane) is an exclusive right-turn lane and the left-hand lane is a shared right-turn/thru lane
2. Exclusive dual right-turn lanes: both the right-hand lane and the left-hand lane are exclusive right-turn lanes

Exclusive dual right-turn lanes are generally preferable because they provide more capacity enhancement. Exclusive dual right-turn lanes also allow for placement of a bicycle lane between the through lane and the right-turn lanes.[90]

The shared right-turn/thru lane has lower lane utilization than an exclusive right-turn lane because thru vehicles block right-turning vehicles during protected right-turn phases; the lower lane utilization may result in the need for longer storage in the curb right-turn lane. In addition, shared dual right-turn lanes, do not allow for placement of a bicycle lane between the shared right-turn/thru lane and the exclusive right-turn lane (or between the exclusive thru lane and the shared right-turn/thru lane). However, shared dual right-turn lanes are preferred where:

- More flexibility is needed to use an optional lane
- Less impacts on the adjacent through movement is desired
- Right-of-way for providing an additional turn lane is restricted

By statute[91], Right turns on red (RTOR), when permitted, are only allowed from the right-hand (i.e., curb) lane of exclusive dual right-turn lanes Pull the curb lane out beyond the left-hand turn lane so drivers in the curb lane have a clear unobstructed view of approaching traffic.. Consider prohibiting right-turn-on-red (RTOR) from a dual right-turn lane if one or more of following conditions exist:[92]

- Insufficient sight distance
- Frequent presence of pedestrians

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[87] *(34) Development of Warrants for Installation of Dual Right-Turn Lanes at Signalized Intersections.* SWUTC/12/161141-1*.* Texas Transportation Institute, Texas A&M University, 2012. http://d2dtl5nnlpfr0r.cloudfront.net/swutc.tamu.edu/publications/technicalreports/161141-1.pdf., p.91-95 / 107-111pdf
[88] Reference (34), p.18 / 34pdf
[89] Reference (34), p.91 / 107pdf
[90] Reference (34), pp34-35, 94 / 50-51, 110pdf
[91] Section 346.37(1)(c)3, Wis. Stats
[92] Reference (34), p.95 / 111pdf

- Use of split phase
- Significant U-turns from right-hand cross-street
- High crash history
- High-speed road, onto which subject RTOR vehicles turns
- Inadequate capacity of receiving lanes

There are some potential issues with dual right-turn lanes, including[93]:

- Sideswipes between turning vehicles are a possibility at double turn lanes. This is especially an issue if the turn radius is tight and large vehicles are likely to be using the turn lanes. Delineation of turn paths should help address this issue.
- Impaired intersection sight distance (ISD) for drivers in the right-hand turn lane due to vehicles in the left-hand lane obstructing their view of on-coming traffic
- Right-of-way acquisition may be expensive.
- Possible access restrictions to adjacent properties
- Dual right-turn lanes make crosswalks longer, which can affect minimum cycle time, increase pedestrian exposure, and precipitate long pedestrian clearance intervals that may or may not work with coordination timing plans.
- Pedestrian movement may also be less safe because a vehicle in the curb lane whose driver is yielding to a pedestrian can block sight lines for drivers in the left-hand turn lane

Design considerations for dual right-turn lanes include[94]:

- Check all turning paths of dual right-turn lanes with truck turning templates allowing 2-ft.between the tire path and edge of each lane.
- Provide a separation between vehicles turning side-by-side of 4-feet desirable / 3-feet minimum.
- Turn lane widths for dual right-turn lanes are 12-ft desirable and 11-ft minimum.
- The minimum width of channelized roadway for dual right-turn lanes is 30-feet, not including gutters.
- Determine the length of dual right-turn lanes as discussed in FDM 11-25-2.
- WisDOT's practice[95] is to assume that the Intersection Design Vehicle (see FDM 11-25-2, Table 2.1) turns from the left-hand lane of the dual right turn lanes (see Figure 10.2). However, there may be locations where it is appropriate to assume that the Intersection Design Vehicle turns from the right-hand lane (for example, a significant number of the vehicles are making a right turn at a close by downstream intersection or driveway). Desirably, the vehicle in the other lane (typically, the right-hand lane) should be a SU truck but, as a minimum, can be a passenger car[96], if any or all of the following conditions are present:
    - Right-of-way is limited
    - Trucks are prohibited on cross streets
    - Cross street volume is minimal (< 400 ADT) and route is unlikely to be used as a detour route for a nearby higher volume roadway

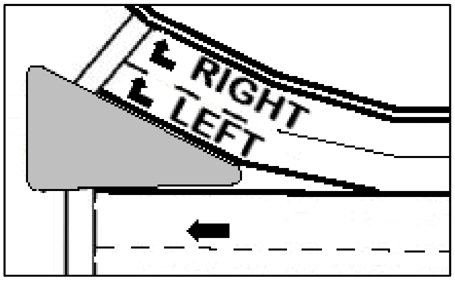

***Figure 10.2* Dual Right-Turn Lanes**

[93] Reference (34), pp5, 41-42 / 21, 57-58pdf
[94] Reference (34), pp5-14 / 21-30pdf
[95] per interim TSDM 3-3-4, July 2009
[96] ILDOT Bureau of Design and Environment Manual 2002 (*9) ILDOT Bureau of Design and Environment Manual ch. 36*: *Intersections*. Illinois DOT, 2002. http://www.dot.state.il.us/desenv/BDE%20Manual/BDE/pdf/chap36.pdf. sect. 36-3.05(b), "Dual Turn Lanes / Design"

- Dual right-turn lanes require sufficient turn radii to allow a smooth turn from both turn lanes, but not so large as to encourage excess speed.
- Provide adequate throat width on the intersection leg receiving the dual right turns to compensate for turning vehicles offtracking and for the relative difficulty of side-by-side right turns. Provide throat widening comparable to that used for dual left-turn lanes (see FDM 11-25-5.4.3.1.1, including Table 5.3 and Figure 5.4). Consider how throat widening will affect the traffic approaching from the other side. Make sure that the through lanes line up relatively well to ensure a smooth flow of traffic through the intersection.
- The receiving roadway needs to carry two through lanes a sufficient distance to allow the effective utilization of both lanes (As a minimum, use the desirable values from the “Tangent Prior to Merge” column in Table A.2.2, from FDM 11-25 Attachment 2.2) - but not less than 150-ft.
- Truck traffic utilization is an issue when designing dual right-turn lanes. Similar to a roundabout, if designed too wide to accommodate truck traffic, then traffic may create a "third turn lane", especially during snowy conditions.
- Avoid installing dual right-turn lanes near access points (e.g., from gas stations, parking lots, or other traffic generators).
- For closely spaced intersections, if a downstream intersection uses dual right-turn lanes, do not align the curb right-turn lane with any through lane at the upstream intersection.
- Provide adequate signing and marking to make the intended operation clear to every road user. Each turn lane should be marked with turn arrows and "ONLY" legends as appropriate. Use lane line extensions to delineate the turning path through an intersection in order to reduce the potential for sideswipe collisions and to increase the efficiency of right-turn operations. Determine lane line (or guideline) and width requirements by plotting the swept paths of the selected design vehicles. There should be no conditions that obscure, or result in, confusing pavement markings within the intersection.

10.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

13. Bonneson, J. A. and M. D. Fontaine. NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements. TRB, National Research Council, Washington, DC, 2001. http://onlinepubs.trb.org/onlinepubs/nchrp/esg/esg.pdf. [97]

33. Cooner, S. A., S. E. Ranft, Y. K. Rathod, Y. Qi, L. Yu, Y. Wang, and S. Chen. Development of Guidelines for Triple Left and Dual Right-Turn Lanes: Technical Report. FHWA/TX-11/0-6112-1. Texas Transportation Institute, Texas A&M University, College Station, TX, Jan., 2011 Published July 2011. http://tti.tamu.edu/documents/0-6112-1.pdf. Accessed 7-24-2012.

[97] [Dec 3, 2012 email from Ellen Chafee, Editor, CRP-TRB] The TRB through the National Academy of Sciences (NAS) grants permission to use the material listed below from Maze et al. (2010) NCHRP Report 650:Median Intersection Design for Rural High-Speed Divided Highways and J. A. Bonneson and M. D. Fontaine (2001) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements in a proposed revision to Chapter 11, Section 25 of Wisconsin DOT’s Facilities Development Manual (FDM 11-25).
NCHRP Report 650 Table 19 p. 47
NCHRP Report 650 Figure 117 p. 148
NCHRP Report 650 Figure 31 p. 49
NCHRP Report 650 Figure 65 p. 86
NCHRP Report 650 Figure 48 p. 65
NCHRP Report 457 Figure 2.6 p. 23
NCHRP Report 457 Figure 2-6.xls Interactive spreadsheet in online version
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34. Yi, Q., C. Xiaoming, D. Li, and Center for Transportation Training and Research - Texas Southern University. Development of Warrants for Installation of Dual Right-Turn Lanes at Signalized Intersections. SWUTC/12/161141-1. Texas Transportation Institute, Texas A&M University, College Station, TX, Apr., 2012. http://d2dtl5nnlpfr0r.cloudfront.net/swutc.tamu.edu/publications/technicalreports/161141-1.pdf. Accessed 1-9-2013.

FDM 11-25-15 Turning Roadways (Channelized Right) *March 4, 2013*

15.1 Criteria

At intersections with a considerable number of turning movements, especially by trucks, and where it is desirable to maintain a turning speed for passenger vehicles of roughly 15 mph (25 km/h) or greater, a separate turning roadway or channelized right-turning lane should be provided between intersection legs. Check the turning movements of OSOW vehicles if needed (see FDM 11-25-2, Table 2.2). Verify that OSOW vehicles are not prohibited from turning at the intersection where needed.

The term "turning roadways" also applies to ramps and ramp terminals, particularly at the crossroad. Refer to FDM 11-30 Attachment 1.3, 1.4, 1.5, and 1.6 for geometrics at ramp terminals.

15.2 Speed And Curvature

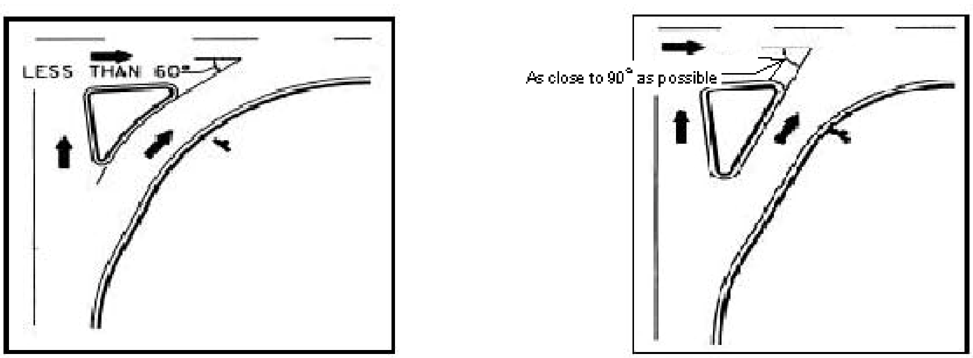
The speed maintained on the free flow segment of turning roadways is governed by the radius of curve and superelevation (see FDM 11-10-5 for superelevation guidance). "Free-Flow Turning Roadways at Intersections" are discussed on pages 639-649, GDHS.

Compound curves should be used at the downstream connection with the departure leg of the intersection to avoid vehicle encroachment onto the curb or shoulders. Three-centered compound curves for vehicles of different design classification are shown in Exhibit 9-20, pages 584-591, GDHS[98]. It is desirable that the right turn radius be kept as small as possible to avoid excess speed, while still accommodating the Intersection Design Vehicle.

15.3 Design Guides

The width of turning roadways should accommodate the design class of vehicle that is anticipated. For turning lanes that are longer than 50 feet, provisions should be made to pass a stalled vehicle in the turning lane. The design width of pavement for turning roadways is shown in Exhibit 3-51, page 220, GDHS[99] with 15 feet as a minimum plus the gutter width. "Turning Roadways with Corner Islands" are discussed on pages 634-639 GDHS.

Channelized right turns should be brought in as close to perpendicular as possible for vision to the left. Right turn lanes separated by islands having intersecting angles less than 60 degrees with the cross street require the driver to look back over their left shoulder to view oncoming traffic, which is particularly difficult for older drivers. Design right turn islands in urban/suburban areas with the right-turn lane at an angle as close to 90-degrees as possible, based on the guidance in FDM 11-25-2.7, “Angle of Intersection”, and as shown in Figure 15.1.



Not Recommended Recommended

Figure 15.1 Intersection Angle for Channelized Right Turn

The taper on the approach to the turn is dependent upon design speed, but 20:1 is typical with 10:1 as a

[98] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[99] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

practical minimum for most urban streets. Use this taper on the receiving leg of the turning roadway as well.

Consider the type of controls to use for channelized right turns. Typically, it is preferred to use a less restrictive method and increase the degree of control as volumes, safety, and geometric conditions dictate. Refer to TSDM 3-4-2 for guidance on control of channelized right turns at signalized intersections.

Provide offsets to raised curb islands as described in FDM 11-25-25.2.1.

15.4 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-20 Median Openings — March 4, 2013

20.1 Introduction

Median openings, whether they are located at major intersections or serve traffic generators between intersections, all tend to interrupt through traffic flow. On arterial streets, it is highly desirable to maintain a free flow of traffic without interruptions.

Median openings accommodate left-turn movements and/or u-turn movements from the highway; and/or also accommodate cross traffic movements and/or left-turn movements from a side road or driveway. A full median opening allows all movements. A directional median opening (Figure 20.1 and Figure 20.2) allows some but not all movements - but has fewer conflict points - and has been found to reduce crash rates.

Provide a pedestrian crossing where the side road has sidewalks on one or both sides of the street and the through street has sidewalk on the opposite side. This condition establishes a legal crosswalk whether the crosswalk is pavement marked or not per ss340.01 (10) (b).Also providing median refuge for pedestrian and share-use path crossings may influence median nose design. See FDM 11-25-5 and FDM 11-46-10.

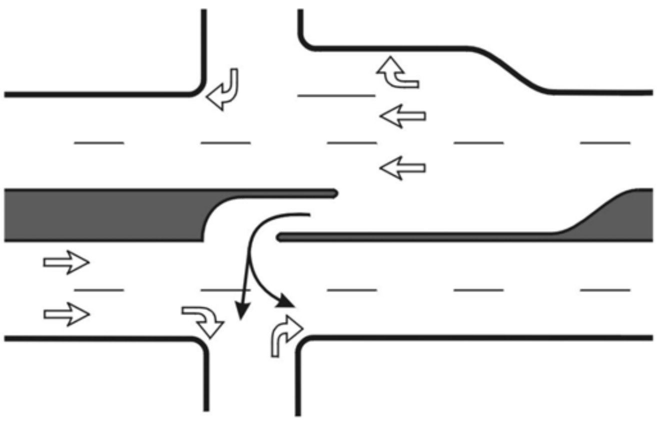


Figure 20.1 Directional Median Opening[100]

[100] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-4 on p.207. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.

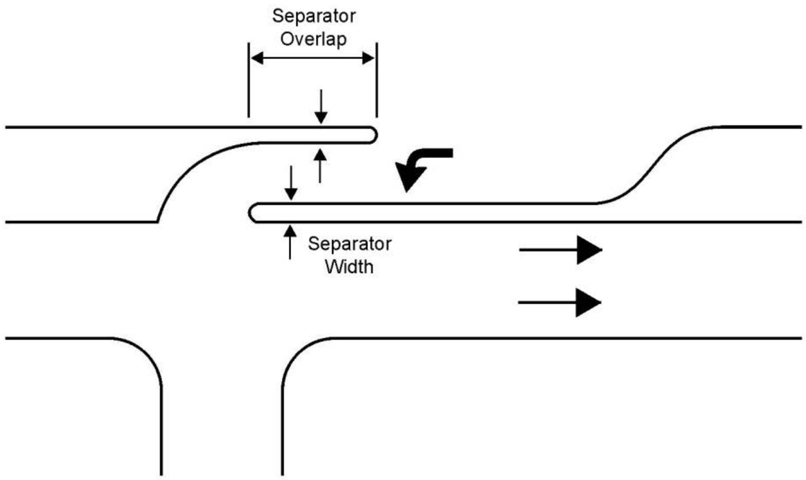


Figure 20.2 Separator Overlap for Directional Median Opening[101]

If there is sufficient space, providing unsignalized directional openings between signalized intersections facilitates access to abutting properties and reduces U-turns / left turns at the signalized intersections. The operations of the adjacent signalized intersections are of greater importance than the midblock opening(s). The midblock opening(s) must not compromise the design or operations of the signalized intersections.

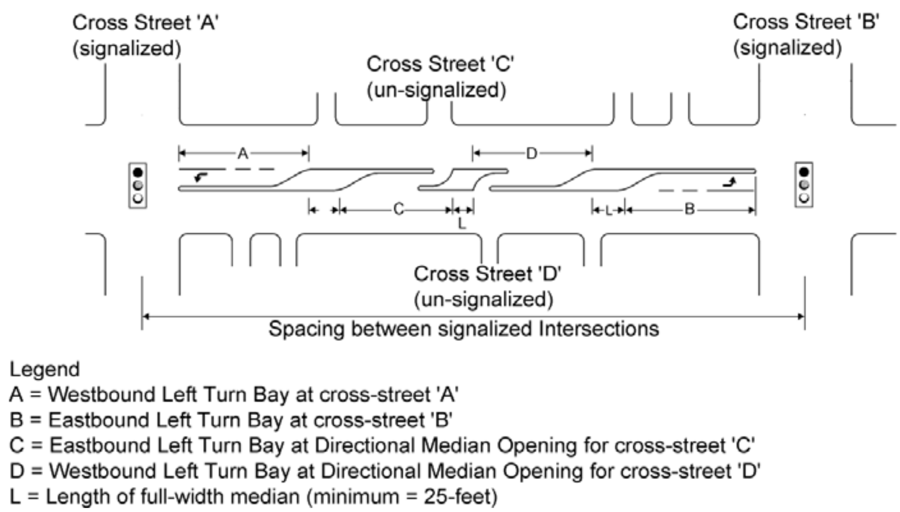


Figure 20.3 Examples of Directional Median Openings between Signalized Intersections[102]

See Table 20.1 below. Also, see AASHTO GDHS, pp.689-712[103] for additional guidance on median openings.

20.2 U-Turns

Median openings for U-turns may be appropriate at some locations, such as:

- In advance of some signalized intersections,
- Downstream from intersections where side road traffic thru movement is not allowed

[101] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-7, p. 209. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.
[102] Adapted from (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-5, p. 208. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.
[103] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

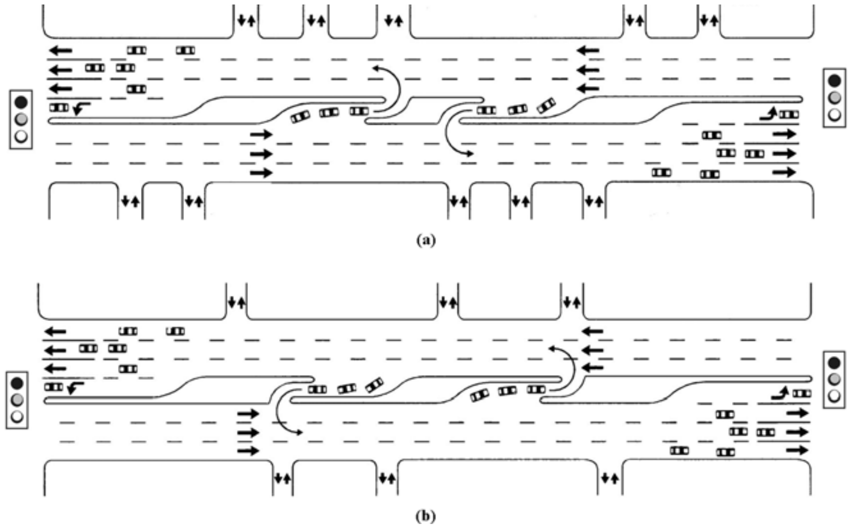


***Figure 20.4 Directional Median Openings for U-turns*[104]**
(a) Downstream from Signalized Intersection
(b) Upstream from Signalized Intersection

See Table 20.1 below. Also, see AASHTO GDHS, pp.709-712[105] for additional guidance, including minimum widths of medians required to accommodate U-turns. Also, see chapter 11 of the TRB Access Management Manual.

20.3 Length of Opening

Use the control radii for vehicles making a left-turn or making a U-turn to determine the length of a median opening. The minimum median opening length is 40-feet. See AASHTO GDHS, Exhibits 9-76 to 9-83[106]. Also, see FDM 11-25-5.3 for guidance on control radii and median end design.

20.4 Spacing

Provide median openings only at locations that are safe for all allowed movements. Also, provide adequate spacing for traffic weaving in order to preserve traffic flow and for safe lane changes and turns.

At a signalized intersection, do not provide a median opening that crosses a left turn lane or left turn storage.

The functional area of an intersection is the critical area where motorists are responding to the intersection, decelerating, and maneuvering into the appropriate lane to stop or complete a turn. Access connections too close to intersections can cause serious traffic conflicts that impair the function of the affected facilities. Drivers need sufficient time to address one potential set of conflicts before facing another.

Ideally, do not place a median opening for a public access intersection (street or alley) or a private access intersection (driveway or private road) within the upstream functional area of another intersection. A median opening within the limits of an exclusive left-turn bay or within the downstream functional area of an intersection is especially un-desirable because it violates driver expectancy and can have a negative effect on the safety, operation and capacity of an intersection.

See Table 20.1 for guidance on evaluating existing and proposed median openings.

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[104] (*11)Access Management Manual*. Transportation Research Board, 2003., Figure 11-8, p.210. Copyright, National Academy of Sciences, Washington, D.C., 2003. Reproduced with permission of the Transportation Research Board.
[105] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[106] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004..

***Table 20.1** Median openings – allowable locations (applicable to STH and connecting highways)*

Median Opening location Relative to Functional Area of intersection [B]	Conditions and Requirements for Median Openings [A]	
	Existing opening (includes formerly undivided roadways on which a new median is added)	New Opening
Inside downstream functional area of intersection for approach lanes and/or for opposing lanes	* **CLOSE** median openings at these locations. Do not consider leaving these open under any circumstances; and * Evaluate and improve the operation and geometry of adjacent intersection to accommodate any increase in turning movements resulting from closing the median opening.	**DO NOT ALLOW**
upstream of (d1) AND Outside of Functional Areas for adjacent intersection	* Construct a separate turn bay for the opening if the opening is inside the left-turn bay for the downstream median opening; and * Make any modifications necessary to correct safety, design and/or operational deficiencies.	* The proposed location meets applicable access, intersection and median opening spacing standards; and * Sufficient sight distance, turning geometry, storage and deceleration can be provided for all allowed movements; and * The projected design year level of service is D or better for all allowed movements; and * Either a full or a directional median opening is allowed. The opening and its associated turn bay(s) must be separate from the left-turn bay(s) for the adjacent median opening(s).
Inside (d1)	* Construct a separate turn bay if the opening is inside the left-turn bay for the downstream median opening ; and * Do not allow additional movements at a directional median opening. * Close or restrict a full median opening to a directional median opening if level of service is worse than D or if there is a crash problem associated with the opening; and * Close or restrict a directional median opening if level of service is worse than D or if there is a crash problem associated with the opening; and * Make any modifications necessary to correct safety, design and/or operational deficiencies.	* The proposed location meets applicable access, intersection and median opening spacing standards; and * Sufficient sight distance, turning geometry, storage and deceleration can be provided for all allowed movements; and *The opening and its associated turn bay(s) must be separate from the left-turn turn bay(s) for the adjacent median opening(s); and * The projected design year level of service is D or better for all allowed movements; and * Do not allow left-outs and thru movements from side roads / driveways and left-ins from the opposite-direction mainline unless meeting the conditions in Note [D] below.
Inside (d2)	It meets the conditions in Note [C] below.	**DO NOT ALLOW**
Inside (d3)	* **CLOSE** median openings at these locations. Do not consider leaving these open under any circumstances; and * Evaluate and improve the operation and geometry of adjacent intersection to accommodate any increase in turning movements resulting from closing the median opening.	
Inside (d4)		
Inside Mainline design hour queue		

Notes

A Evaluate each opening for both directions of travel, and for both peak and non-peak conditions. If movement restrictions or prohibitions are ineffective or impractical then close median opening.

B The upstream functional lengths for the thru lane(s), left turn bay, and right turn bay determine the boundary for the upstream functional area of intersection.

Upstream functional length of intersection elements d1, d2, d3, and d4 are independent of turn bay elements although, ideally, they correlate as shown in FDM 11-25-2, Figure 2.9. However, this correlation is not always possible, or may change because of changes in traffic at an intersection.

C Consider allowing an existing opening to remain only if there is a written request from a municipality to do so. This request must contain acceptable documentation for all of the following:

- Design alternative for closing the existing opening that evaluates alternate accesses, operations and safety and includes a good faith comparison showing that keeping the existing median opening is the preferred alternative.
- Minimum of the most recent available 3-year crash history showing that there is not a crash problem associated with the existing median opening. Crashes that might be associated with the opening can occur at the opening but also up to several hundred feet from the opening in both directions of travel. Examples include:
    - Crashes involving vehicles in the approach thru lane forced to decelerate or stop because of spillback from the median opening.
    - Crashes involving vehicles from a side road or driveway that are making left-out or thru movements.
    - Crashes involving vehicles from the opposing lane that are making left-in or u-turn movements.
    - Crashes involving vehicles unable to clear the intersection because of queuing in the opposite-direction mainline at the median opening.
    - Crashes involving vehicles from the turn lane that are making left-in movements.
- The existing opening is not within the design storage queue of either the turn lane or the mainline.
- Evaluation and proposed improvements of adjacent intersections capability to accommodate increased turning movements resulting from restrictions at the existing median opening.
- There is adequate storage and deceleration length available for same-direction left-in movement at the existing median opening.
- Prohibit left-outs and thru movements from side roads / driveways and left-ins from the opposite-direction mainline unless meeting the conditions in Note [D] below.
- The design hour level of service for any of the allowed movements at the existing opening is C or better, and the design hour level of service for the intersection is C or better.
- The municipality agrees to close the opening if:
    - the design hour level of service deteriorates to D or worse, or
    - there is a crash problem, or
    - the design storage queue for either the turn lane and/or the same-direction mainline extends into the median opening

D Movements that are prohibited during certain times of day can be allowed during other times of day if all of the following conditions are met:

- Sufficient median width and turn bay length must be available for all allowed movements.
- Levels of service for all allowed movements shall be C or better.
- Signing that prohibits these movements at all other times shall be installed.

20.5 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

11. TRB Committee on Access Management (ed.) (ed.). Access Management Manual. Transportation Research Board, Washington, DC, 2003.[107]

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FDM 11-25-25 Channelization

March 4, 2013

25.1 General

Traffic can be channelized by using various combinations of islands, pavement markings, rumble strips, contrasting pavement, traffic signals, etc. The design guides for providing left- and right-turn lanes (FDM 11-25-5 and FDM 11-25-10) are also methods of channelizing traffic.

25.2 Islands

This discussion assumes that islands are raised by using curb and gutter. The use of islands for directing traffic should be held to a practical minimum, as they in themselves can present problems, especially for winter maintenance activities. The desirable minimum size for islands is 150 square feet; the minimum size is 100 square feet. The approach end of the island should provide sufficient warning to identify the island's existence. This can be accomplished by using a raised delineator (non-rigid) or a rumble strip. To prevent damage to snowplows or errant vehicles, a mountable curb should be constructed on the approach nose.

Islands may also need to provide for pedestrian crossing. The crossing area needs to be unobstructed with a flat, level surface.

Minimize channelization islands, raised islands and other raised features that may inhibit turning movements of OSOW vehicles on the OSOW Freight Network.

25.2.1 Offsets

The approach nose of a curbed island needs to be conspicuous to approaching drivers - and definitely clear of the vehicle path, both visually and physically, so that drivers will not shy away from the island. Where possible, offset median islands 8 feet from the travel lane and transition to a normal curb offset, - typically 2 feet. The transition length is dependent on the design speed.

Offsets from the edge of thru travel lane to the face of a curbed channelizing island for a turning roadways are as follows (these offsets include a continuation of the width provided for on-street bicycle accommodation (see SDD 15C29)):

Low speed urban roadways (posted speed of 40 mph or less)

- If the offset to curb face from the outside edge of approach travel lane is <=2-ft then offset the approach nose of the right turn channelizing island by 4-ft from the outside edge of the travel lane and taper down to a 2-ft offset at the departure nose.
- If the offset to curb face from the outside edge of approach travel lane is >2-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal offset at the departure nose.

Transitional and high speed urban roadways (posted speed of 45 mph or greater)

- If the offset to curb face from the outside edge of approach travel lane is <=6-ft then offset the approach nose of the right turn channelizing island by 8-ft from the outside edge of the travel lane and taper down to a 6-ft offset at the departure nose.
- If the offset to curb face from the outside edge of approach travel lane is >6-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal offset at the departure nose.

Rural roadways

- If the outside finished shoulder width is <=6-ft then offset the approach nose of the right turn channelizing island by 8-ft from the outside edge of the travel lane and taper down to a 6-ft offset at the departure nose.
- If the outside finished shoulder width is >6-feet then offset the approach nose of the right turn channelizing island by an additional 2-ft from the outside edge of the travel lane and taper down to the normal shoulder width at the departure nose.

Offset the edge of a channelized turning roadway by 2-3 feet from the face of a curbed channelizing island at the approach nose and continue this offset to the departure nose.

25.2.2 Signalized Intersection Considerations

As discussed in FDM 11-25-10, right-turn pork chop islands are typically provided for delineation, pedestrian refuge, and traffic signal placement at intersections with flat radii. Revisions to a signalized intersection will

2. None of this material may be presented to imply endorsement by TRB of a product, method, practice, or policy.

typically be needed at some point in the future. Therefore, the construction of islands is very important. Monolithic concrete islands are not desirable because installing a pull box or base would require removing concrete.

25.3 Pavement Markings

Painted islands should not be offset from the through lane except where the lane width is insufficient. For additional discussion, refer to pages 621-639 of GDHS[108].

25.4 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-30 Curb Ramps *October 5, 2011*

This portion of the FDM has been transferred to FDM 11-46-10.

FDM 11-25-35 Auxiliary Lanes *March 4, 2013*

35.1 Auxiliary Lanes

An auxiliary lane is defined as the portion of roadway adjoining the traveled way such as turning lanes, storage for turning, weaving, or the added lane between two interchange ramp areas, and other purposes supplementary to through-traffic movement.

Truck climbing lanes and passing lanes are not considered auxiliary lanes. For more information on truck climbing lanes and passing lanes see FDM 11-15-10.

35.2 Acceleration Lanes

For design details of acceleration lanes refer to FDM 11-30-1. Acceleration lanes may also be used at non-signalized intersections with turning roadways, particularly for right-turning vehicles entering an arterial. In some cases, a length of the parking lane may become the acceleration lane. For details relating to a tapered or a parallel type of acceleration lane, refer to pages 688-689, GDHS[109].

35.3 Bus Stops

Bus transit is an integral part of the operation of many urban streets and highways. The existing operating policies and the future transit needs of communities should be given design consideration where applicable, particularly where bus movements caused by bus stops will affect intersection capacity.

A bus stop area, landing pad or platform is the portion of roadway designated for transit users to facilitate boarding and alighting[110]. A bus stop connects to an intersection corner, sidewalks, or paths by an accessible route. Connections directly to the roadway are not permitted because roadways are not pedestrian facilities. The minimum requirements for a bus stop site are:

- A firm, stable surface with a 2% cross slope;
- A minimum clear length of 96 inches, measured from the curb or vehicle roadway edge;
- A minimum clear width of 60 inches, measured parallel to the vehicle roadway;
- A bus stop area, landing pad or platform must meet ADA design standards.

Other transit facilities that should be considered for buses are bus passenger shelters, park-and-ride lots, and turnouts (separate loading lane). The decision to include bus turnouts should be based on the volume and turning movements of both the bus traffic and through traffic, the distance between bus stops, and right-of-way limitations. The design features for turnouts should be based on the size and turning radius of the bus. Generally, turning radii should be such that buses can remain in the outer lane during the full turn. For a more

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[108] *(1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[109] *(1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[110] *(35) Toolkit for the Assessment of Bus Stop Accessibility and Safety.* Easter Seals Project ACTION, 2006. http://www.transitaccessproject.org/InternalDocs/TransitFacilities/06BSTK_Complete_Toolkit.pdf;http://www.nelsonnygaard.com/Documents/Articles/Complete_Toolkit-new.pdf.
Note: This is listed as a reference by FHWA at http://safety.fhwa.dot.gov/ped_bike/ped_transit/ped_transguide/ch1.cfm, "Pedestrian Safety Guide for Transit Agencies"

complete discussion of bus considerations, see pages 367-373, GDHS[111].

FDM 11-25-40 Railroad Crossings *March 4, 2013*

40.1 General

If there is a railroad crossing on a project, include the region railroad coordinator early in project scoping and thereafter during project design.

FDM 17-60-5 establishes railroad grade crossing design criteria. FDM 17-40-5 explains factors to consider when evaluating the potential need for a grade separation structure. All signing, marking, signals, and gate installations shall conform to the Manual on Uniform Traffic Control Devices, FHWA, 2000 and the Wisconsin Supplement. Additional information can be found on pages 731-739, GDHS[112]

Sight distance triangles should be provided for vehicles approaching a crossing, but a separate sight distance triangle must be provided for vehicles such as buses and trucks, which are required to stop. Stopped vehicles need additional sight distance to proceed safely across a railroad crossing. An additional lane should be considered for stopped vehicles, particularly on multi-lane highways.

On new construction, reconstruction and pavement replacement projects being designed with Civil 3D software and using a 3D model check the 5-axle expandable-deck lowboy (DST Lowboy) OSOW-ST vehicle at railroad crossings on the OSOW Freight Network (FN) to ensure sufficient vehicle body clearance so that vehicles can cross the tracks without “hanging up”. See FDM 11-25-1.4 for information on the OSOW Freight Network (FN). See FDM 11-25-2.1.1 and Attachment 2.1 for information on OSOW vehicles.

40.2 References

1. A Policy on Geometric Design of Highways and Streets 2004, 5th edition. AASHTO, Washington, DC, 2004.

FDM 11-25-45 Frontage Roads *March 4, 2013*

A service road (also commonly referred to as a frontage or backage road) is a public or private street or road that runs generally parallel to but is separated from the major roadway by a physical barrier. Its primary function is to provide access to the abutting properties. Service roads are also referred to commonly as frontage or backage roads.

A frontage road is a service road between the right-of-way of the major roadway and the front building setback line. It provides access to properties while separating them from the principal roadway. Frontage roads will “front” on the major roadway.

A backage road is a service road that is separated from the major roadway by intervening land uses. The arterial abuts the rear lot line and buildings may face the backage road. Buildings on backage roads face away from the major roadway.

Freeway/expressway interchange areas that have frontage road access to the crossroad outside the ramps are addressed in FDM 11-5-5.

Service roads provide the following benefits:

- Effectively control access to the through lanes on the arterial street,
- Provide access to adjoining property,
- Separate local traffic from through traffic, and
- Permit circulation of local traffic adjacent to the arterial.

From an operational and safety standpoint, one-way service roads on each side of an arterial may be preferred to two-way service roads.

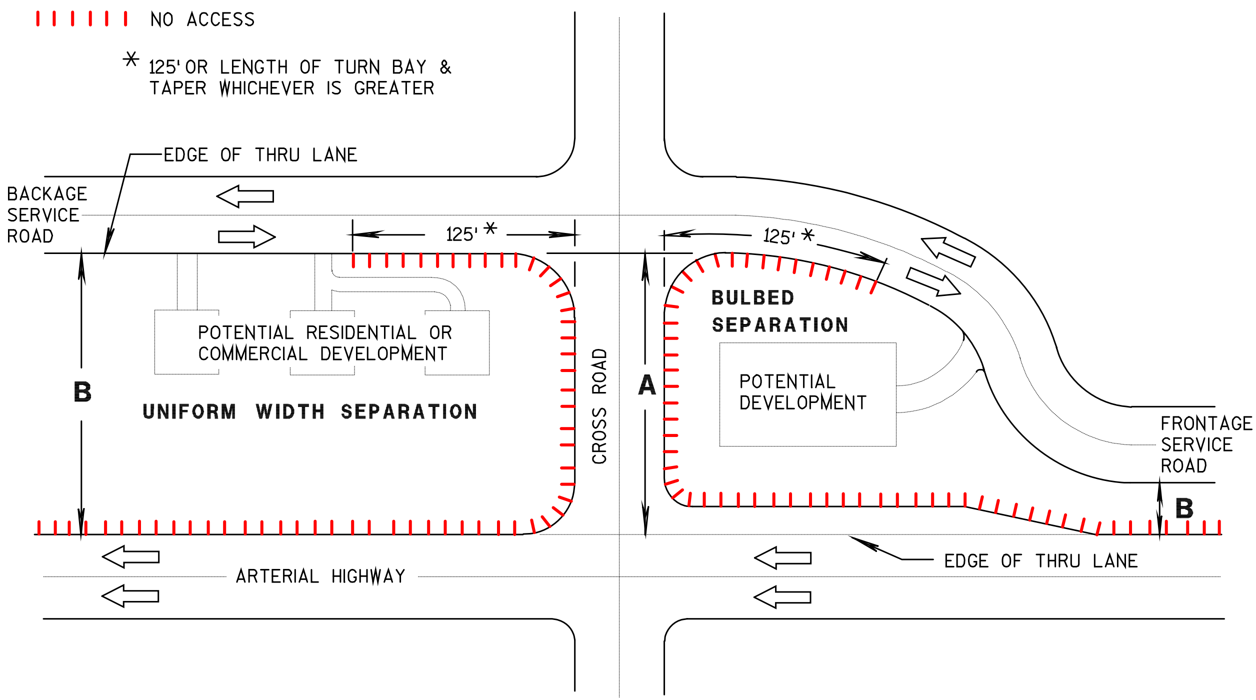
Maximize the separation distance between the service road/crossroad intersection and the arterial/crossroad intersection to ensure sufficient storage for traffic on the crossroad between the service road and the arterial. At some time the arterial/crossroad intersection may be signalized or include a roundabout. Provide adequate storage for queued vehicles.

The absolute minimum separation distance (Dimension A in Figure 45.1) is 150 feet in a tightly constrained urban environment with low crossroad traffic volumes. This is the shortest length for placing signs and other

[111] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.
[112] (*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

traffic control devices. Greater distances are needed to provide adequate vehicle storage and to separate operation of the two intersections. Spacing of at least 300-feet, preferably more, in urban areas enables turning movements to be made from the arterial lanes onto the service road without seriously disrupting arterial traffic. High crossroad traffic volumes with high service road volumes will typically justify a greater separation distance. This may be achieved by taking the service road around an existing or proposed development as shown in the "bulbed separation" area, in effect developing a backage road for that portion of the otherwise frontage road. A greater separation than those shown in Figure 45.1 may be needed if signalization is required. The recommended separation distance between signals is about 1,300 feet, unless the signals are coordinated like the close spacing between interchange ramps. The separation between properly designed roundabouts may be 300 feet or less in tight situations.

Away from the arterial intersection consider the distance separating the service road travel lanes from the arterial travel lanes, distance "B" on the bulbed separation" side of Figure 45.1. Headlight glare, driver confusion about the location of an approaching vehicle and errant vehicles are safety concerns that suggest keeping that distance as wide as practical. In tight built-up urban areas, this distance may be as low as 45 feet. In situations that present a safety concern, glare fence or other protective shielding may be required between the service road and the arterial.



Min. Distance **A**[113] (stop control)		
Crossroad Design year AADT	Distance (ft)	
	Urban	Rural
< 100	150	300
100 – 1,000	300	300
> 1,000	600	600

[113] *(36) NCHRP Report 420*: *Impacts of Access Management Techniques*. TRB, National Research Council, 1999. http://www.accessmanagement.info/pdf/420NCHRP.pdf., pp.121-127
(*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004., pp.725-728

	Distance B	
	Urban	Rural
Desirable	85 ft	115 ft
Minimum	45 ft	85 ft
Greater distances may be warranted where noise barriers, berms or landscaping are located along the arterial. Distance ‘B’ for a backage road does not necessarily equal Distance ‘A’ along the crossroad.		

Figure 45.1 Frontage Road Offset Guidelines

45.2 References

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[114] [Dec 3, 2012 email from Ellen Chafee, Editor, CRP-TRB] The TRB through the National Academy of Sciences (NAS) grants permission to use the material listed below from Maze et al. (2010) NCHRP Report 650:Median Intersection Design for Rural High-Speed Divided Highways and J. A. Bonneson and M. D. Fontaine (2001) NCHRP Report 457: Engineering Study Guide for Evaluating Intersection Improvements in a proposed revision to Chapter 11, Section 25 of Wisconsin DOT's Facilities Development Manual (FDM 11-25).

NCHRP Report 650	Table 19	p. 47
NCHRP Report 650	Figure 117	p. 148
NCHRP Report 650	Figure 31	p. 49
NCHRP Report 650	Figure 65	p. 86
NCHRP Report 650	Figure 48	p. 65
NCHRP Report 457	Figure 2.6	p. 23
NCHRP Report 457	Figure 2-6.xls	Interactive spreadsheet in online version

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